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THE RESOURCE STRUCTURE OF UNITED STATES AGRICULTURE: AN ECONOMIC ANALYSIS

Iowa State University PH.D 1979

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The resource structure

of United States agriculture:

An economic analysis

by

Kent David Olson

A Dissertation Submitted to the

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DOCTOR OF PHILOSOPHY

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CHAPTER I. RESOURCE ORGANIZATION AND STRUCTURE IN U.S. AGRICULTURE

Agriculture in the United States has undergone vast changes since the turn of the century. The numbers of farms and farm workers have declined drastically. The average size of farms has increased. Only a small percentage of the horses on farms today is used for work. Agricultural inputs increasingly come from nonfarm sources. World agricultural markets can affect local U.S. markets today. The farm bloc has lost much of its political clout.

These changes have not hampered farmers' ability to produce; indeed, improvements in farmers' ability to produce probably caused these changes. Overall output and productivity in U.S. agriculture have increased tremendously since 1910 while total input has remained fairly constant (Figure 1.1). Aggregate agricultural output in 1977 is 180 percent larger than in 1910 but aggregate input is only 20 percent larger (Table 1.1). Overall productivity has increased by 136 percent in the same period. Crop production per acre has increased by 120 percent. Labor productivity has increased by 1,230 percent since 1910!

The changes in productivity can be linked to changes in the resource or input mix. While the total level of input has remained fairly constant,the proportion of that input that is purchased from nonfarm sources has increased (Figure 1.2). By freeing labor from producing inputs the labor can be used to produce output thus in-

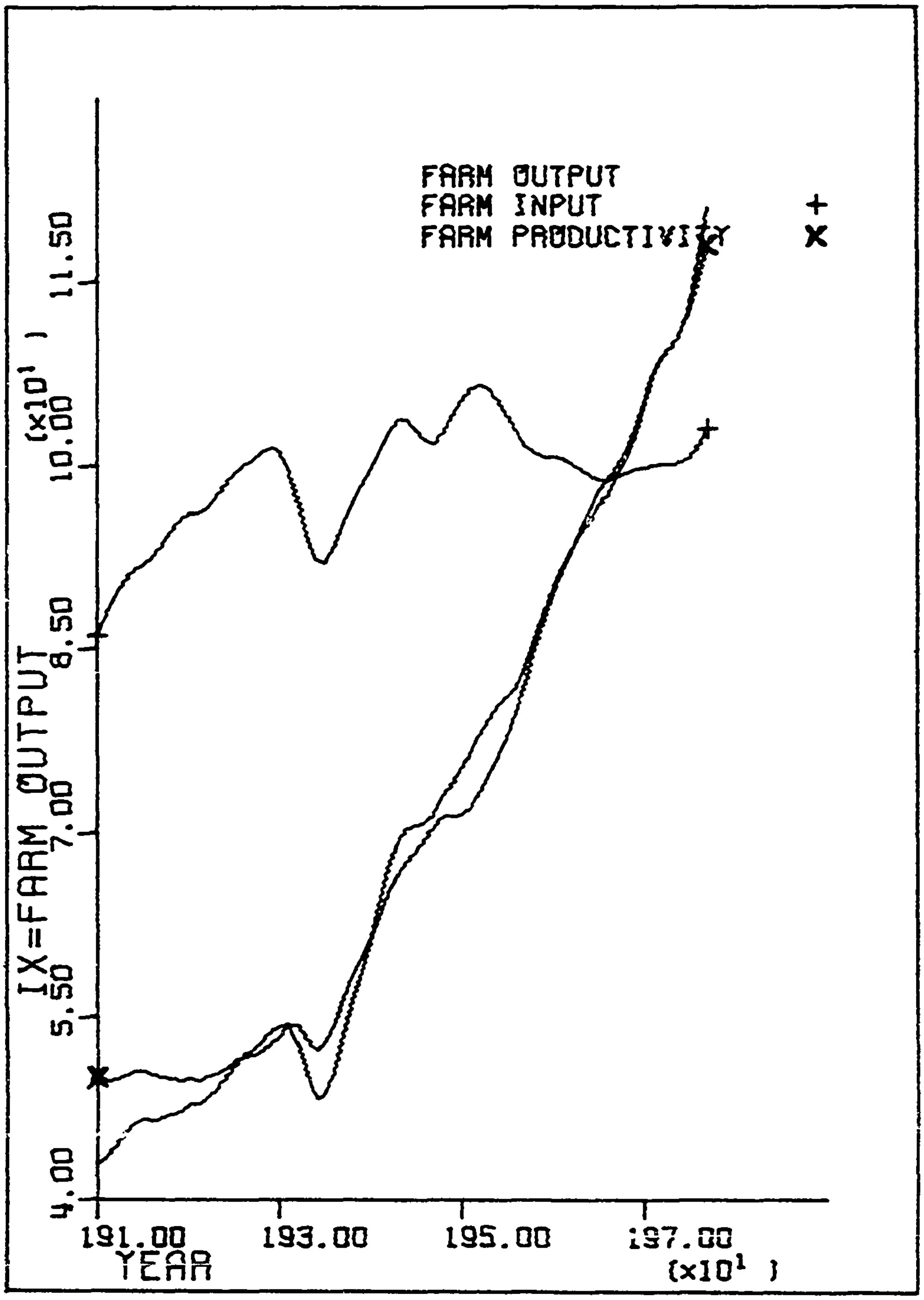

Figure 1.1. Indices of national farm output, input, and productivity, 1910-1977.

Table 1.1. Aggregate output and input and overall, cropland, and labor productivities, 1910-1977, selected years.[a]

Year	Aggregate output	Aggregate input	Aggregate productivity	Crop production per acre	Farm output per labor hour
	- - - - - - - - - -	- 1967 = 100 -	- - - - - - - -	- - - - - - - -	- - - - - - - -
1910	43	86	50	56	13
1920	50	98	52	61	14
1930	52	101	51	53	16
1940	60	100	60	62	20
1945	70	103	68	67	26
1950	74	104	71	69	34
1955	82	105	78	74	44
1960	91	101	90	89	65
1965	98	98	100	100	89
1970	101	100	102	104	115
1975	114	100	115	112	152
1977	121	103	118	116	173

[a]Sources: (Durost and Black, 1978, p. 19, 45, and 69).

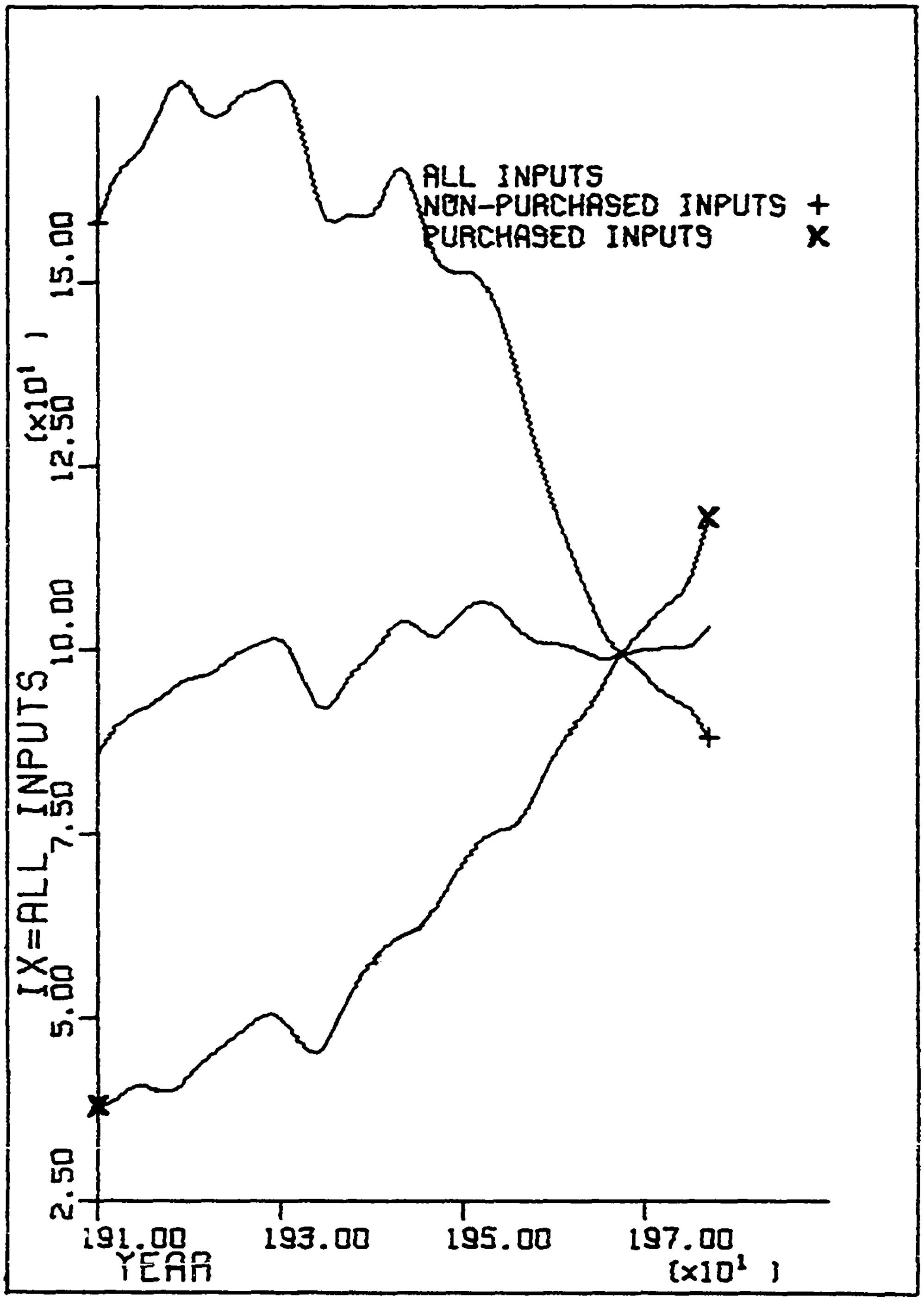

Figure 1.2. Indices of total, nonpurchased and purchased input levels, 1910-1977.

creasing productivity. And as the absolute level of labor decreases as output increases, the productivity of the remaining labor increases. To increase production as labor input decreases, the use of machinery and agricultural chemicals is increased.

The total input level increased by 20 percent since 1910; however, the amount of inputs purchased from nonfarm sources increased by 210 percent while the amount of nonpurchased inputs decreased by 44 percent (Table 1.2). The farm labor force in 1977 is 78 percent less than in 1910. The amount of land used in agriculture is quite stable. Mechanical power and machinery use has increased by 480 percent. The use of agricultural chemicals has increased by 2,920 percent since 1910. The levels of feed, seed, and livestock purchases have increased by 480 percent reflecting larger portions purchased from nonfarm sources and increased demand for livestock products.

These trends in agricultural resource use are not necessarily irreversible or unchangeable. Past changes in resource use were based on agricultural production functions and were responses to economic, technological, environmental, institutional, governmental, and other stimuli. Future changes will be based on production functions, as well, and will be responses to future stimuli. But future stimuli may differ from past stimuli so future changes in resource use may differ from past changes.

This is not saying that future stimuli, and thus resource use, will change. It is quite possible that the stimuli will remain fairly

Table 1.2. Indexes of total agricultural input and major input subgroups, 1910-1977, selected years[a]

Year	Total input			Farm labor	Farm real estate	Mechanical Power and machinery	Agricultural chemicals	Feed, seed and livestock purchases
	All	non-purchased	purchased					
				(1967 = 100)				
1910	86	158	38	321	98	20	5	19
1920	98	180	43	341	102	31	7	25
1930	101	176	50	326	101	39	10	30
1940	100	159	58	293	103	42	13	42
1945	103	161	62	271	98	58	20	54
1950	104	150	70	217	105	84	29	63
1955	105	143	76	185	105	97	39	72
1960	101	119	86	145	100	97	49	84
1965	98	103	93	110	99	94	75	93
1970	100	97	102	89	101	100	115	104
1975	100	92	107	76	96	113	127	101
1977	103	88	118	71	97	116	151	110

[a]Source: (Durost and Black, 1978, p. 56-57).

stable but to assume that no change will occur is naive. For example, the process of education, innovation, and adoption is a continuous process. However, adoption of new technologies of recent years (e.g., chemically-processed fertilizer, hybrid crops, pesticides, etc.) may be so widespread that their impact upon trends or changes in resource use will decrease relative to the impact of other stimuli.

To understand past changes and to forecast future changes in resource use, an understanding of agricultural production functions is needed. These production functions show the relationship between the level of resources and the level of production. And, in reverse, given the demand level for the product, the production function determines the demand for the various resources. This process of determining resource demand is the response to stimuli; the exogenous stimuli exhibit their effects through the resource structure to determine resource demand.

Resource structure is used in this study to refer to the mix of resources used, the size and number of farms, and the demand, supply, and production functions of agriculture. The structural coefficients, the parameters of demand, supply, and production functions, determine the structural organization of agriculture, the mix of resources and the size and number of farms. The structural organization of agriculture is physical and directly measurable; the structural coefficients are discernible as underlying, intrinsic relationships.

It is the organization that changes in response to exogenous and endogenous stimuli. These changes are determined by the underlying structure of agriculture. A structural shift (e.g., technological change or shift in producer preference) causes a different response to the same stimuli.

To estimate the response to stimuli, the structure or derivations from the structure must be known. If governmental policy changes are proposed, the structure or its derivations are needed to predict the impacts upon agriculture. To estimate farmers' response to a fuel tax, the structure itself is needed to quantify the effect and to estimate the impacts upon agriculture as a whole.

This study estimates part of the resource structure of U.S. agriculture. The factors affecting the demand for resources and groups of resources at the national level are analyzed by econometric methods. The significance, magnitude, and direction of the impact of these factors is determined. Elasticities of demand are calculated from this analysis; these show how responsive national resource demand is to a certain factor (e.g., fertilizer demand to the price of fertilizer or the crop price). When they are available, past elasticity estimates are compared to present estimates.

The second purpose of this study is to forecast the future mix or organization of agricultural resources at the national level. The exact values of future stimuli are unknown, but they can be estimated. And by using several sets of values the sensitivity of the future levels and mix of resource can be observed. From this analysis future movements and changes in the resource structure are predicted. Potential effects and (or) problems that may occur under the projections are pointed out and discussed.

These results have several uses. The later analysis can be used to estimate the impact upon resource use of increasing farm income or rising total personal, disposable income in the U.S. The impact of higher fuel prices can be traced through using the results from the first part of this analysis. The effect of rising wages for hired farm workers upon the level of farm employment and upon the demand for farm machinery can be estimated. These are just a few of many possible uses of this study's results. The results can be used by farmers, policymakers, farm input-suppliers, and product-processors.

The analysis of demand for resources is broken into three main sections: machinery and building and land improvements, labor, and operating inputs. Farm labor is divided into its hired and family portions for analysis. In addition to analyzing aggregate demand for operating inputs, the separate categories of seed, fertilizer and lime, pesticides, feed, fuel and oil, and electricity are analyzed. Analysis is done at the national level.

The results are reported after two chapters covering (1) economic theory and models and (2) the statistical procedures and considerations for this study. The three chapters for machinery and building improvements, farm labor, and operating inputs are next;

these lend themselves to separate analysis and so include an introductory discussion of historical trends and summary of the results. Projections of resource mix and organization are presented in the seventh chapter. The last chapter summarizes the results and implications.

CHAPTER II. ECONOMIC THEORY AND MODELS OF RESOURCE STRUCTURE

Using economic theory, models of agricultural resource demand and investment are described in this chapter. These models are general in nature and used in following chapters as examples of the theory followed to develop models specific to the resource being analyzed. These models are taken from the investment literature; new investment theories are not postulated in this study.

The discussion consists of two parts. First, the variables used in this analysis are presented and the reasons for including them are given. Second, the models to be utilized are analyzed.

Variables for Resource Analysis

Within this section the variables used in the analysis of farmers' expenditures for stocks of inputs or resources are presented. The reason or reasons for including each are discussed; potential problems are pointed out.

Prices

Obviously, the prices of products and resources have an important impact upon the use of resources. Under conditions of restricted or unrestricted profit maximization, resource demand fluctuates inversely to resource prices and directly with output prices. Substitute and complementary resource prices affect the demand for a particular resource; this effect is assumed to be positive for substitutes and negative for complements.

Theoretically, the input/output price ratio and the input/input price ratios seem to be better indicators of resource profitability than the absolute price levels. Using a general profit function

$$\pi = P_y f(X_1, X_2, \ldots, X_n) - \sum_{i=1}^{n} P_i X_i \tag{2.1}$$

where P_y and P_i are the prices for the product and ith resource and the function f is the production function, the first-order conditions for profit maximization indicate that resources should be utilized up to the level that equates marginal physical product and the input/output price ratio

$$\frac{\partial f}{\partial X_i} = \frac{P_i}{P_y} \tag{2.2}$$

The input demand functions derived from quadratic production functions have input/output price ratios. However, the input demand functions derived from Cobb-Douglas production functions use absolute price levels.

Most farmers perceive that what is important in decision making is relative prices, not absolute prices. But the farmer works in a world of uncertainty where all prices are not known with certainty. The farmer plans production when resource prices are known and product prices are not known but are perceived or expected to be within a range. Weather adds to the uncertainty of not only product prices but also of the individual farmer's production level and resource productivity. For these reasons, farmers may perceive a greater portion of an input price change as permanent than a proportional change in output price; thus, proportional price changes resulting in constant price ratios may be accompanied by resource use changes. This line of reasoning argues for inclusion of absolute price levels in resource demand functions.

Interest rates

When capital is restricted for a firm, the rate of return on that capital becomes a decision variable for the firm. To cover the cost of borrowing money, an investment or purchase must return the interest charges incurred. Normally, firms will borrow up to the level that the rate of return equals the interest rate on borrowed funds. While individual farmers use their local markets, the Federal Reserve discount rate is used in this analysis as an indicator of overall shifts in borrowing costs. Local variables for interest charges are too numerous to be realistically included in the models. For resources such as farm real estate and buildings, the Federal Land Bank's interest rate on new loans is used.

Net farm income

Net farm income or profit is used to indicate both returns to durable resources and expectations of future financial capabilities. Net farm income calculated as gross income less production expenses adjusted for inventories and government payments is seen as return to durable resources and operator labor. Historically, farmers have imputed little return to their own labor, so net farm income is used mostly to determine profitability of durable assets. It is used also to estimate future profitability (i.e., the return to future durable assets) and thus the amount of durable assets purchased in the current period.

At times, net farm income, as an indicator of future debt payment capacity, overshadows the input/output price ratio in importance. If debt payment capacity is low, new machinery may not be purchased even if the machinery/crop price ratio is low. Conversely, if net farm income is high, machinery may be purchased even if the machinery/crop price ratio is high. This latter case may occur if a farmer wishes to take advantage of certain tax laws to maximize after-tax income by deducting interest payments incurred from land and (or) machinery loans.

External sources of credit may also look at the ability to repay in addition to the profitability of an investment. To a creditor, net farm income may serve as a surrogate measure of management ability and thus, as a measure of the "riskiness" of the loan recipient. The greater the historical net farm income, the more inclined a creditor will be to loan money to a farmer; or, the less profitable a venture is, the greater the historical net farm income must be for a creditor to loan money.

There is also a psychological or social pressure that may enter into the demand for machinery, land, and other resources. The desire to have a larger farm, to drive a newer, bigger machine, to have the highest yields, etc., lead a farmer to utilize resources beyond the profit maximizing level. The ability to buy or rent these resources, rather than their profitability, becomes the decision variable.

Income is determined by prices, weather, technology, and other factors. Some of these can be specified individually in demand functions. With aggregation and problems of intercorrelations the effects of these variables are not always exhibited in the function when entered together. By including net farm income and excluding some of its determinants, some of the detailed information is lost but the full impact of income is estimated. And most farmers would include income in a shorter list of decision variables rather than the complete list of income determinants.

Equity

As with income, equity is often used as a measure of debt payment capacity and as an investment and demand decision variable in addition to profitability. It overshadows profitability in many of the same instances as income did and for many of the same reasons. In addition, an older, established farmer with greater equity will have an easier time in obtaining a loan than a younger farmer with less equity even though both may have the same income flow. An external creditor may also perceive greater equity as an indication of better management (i.e., income that was generated was not "frittered away").

The ratio of proprietors' equity to total liabilities measures what equity itself does and also measures the firms' ability to withstand financial hard times. The amount of financial risk of an investment is greater with a low ratio than with a high ratio. The farmer with a high equity-to-liability ratio will have internal and external sources of funds to finance investment and input purchases that a farmer with a low ratio will not. The equity ratio can also serve as a proxy for past income in that debts are paid off during periods of favorable income before consumption and investment adjusts to the change in income.

Nonfarm/farm income ratio

Nonfarm income or the ratio of nonfarm to farm income is a measure of the opportunity cost or gain between the two sectors. If nonfarm income is high relative to farm income, there tends to be a net movement of workers out of farming to nonfarming occupations. Due to nonmonetary returns to farmers for "being close to the earth" and "the good life", nonfarm income is usually greater than farm income, but when the spread or ratio widens, there is a movement of workers. This income ratio is also a factor in the number of farms and capital investment as it affects the movement of workers.

Unemployment

At times workers may not be able to move from farm to nonfarm occupations even though the income differential is great; the rate of unemployment may be such that there are essentially no jobs to move to. By combining the nonfarm/farm income ratio and the national unemployment rate, this interaction is estimated.

Farm output and productivity

The demand for operating inputs such as fertilizer and fuels and oils may move with output depending upon how large the stochastic elements in output and productivity are. Output can also serve as a proxy variable for demand. Past increases in productivity would indicate a need to increase the level of resource use so that the value of marginal product is equated to the resource price (assuming diminishing returns to larger levels).

Average acreage per farm

Investment in buildings and machinery decreases on a per acre basis as farm size grows according to Hoffmann and Heady (1962). As farmers rent or buy additional land, the demand for additional buildings and machinery for each farm does not increase proportionately. If farmers have more machinery capacity than they presently require and take on more land, operator labor demand may increase but machinery demands may not. If machinery demand does not increase machinery storage demand probably will not either.

Lagged stocks and expenditures

The tendency to "do this year what we did last year" is great in the midst of uncertainty - especially if a profit was made in past years or there is not enough knowledge to change. By including past stock and expenditure levels this idea is captured. This variable alone is the naive model. Other variables are included in the models to capture the factors causing deviations from the trend.

Government income support programs

Greater stability of product prices can influence farmers' investments and expenditures by reducing uncertainty. The greater the chance for profit, the more likely a purchase will be made and (or) resources will be utilized at a higher level. A dummy variable is used to simulate the impact of government programs.

Time

Many other variables are lumped together by time. Lagged effects longer than included explicitly in a model are captured by time. Quality improvements, increases in productivity, and higher levels of knowledge are captured by time. Gradual institutional and social changes are incorporated into the time variable. A time variable is included in most models to capture this "march of time".

These variables discussed above are assembled in the following section into various models. These models attempt to explain, in general, several forms that are used in later chapters.

Models of Resource Demand and Investment

While all the decision variables discussed in the preceding section cannot be incorporated into one model feasibly, several models can be specified giving various factors importance in the functions. In later chapters empirical results as well as a priori considerations are used to select those models giving best results. The following models are general and exemplary in nature and developed more specifically as individual inputs or output groups are analyzed. Some of the models come from microeconomic theory of the firm, others are from those first developed by Koyck (1954) and Nerlove (1958), several are used by Heady and Tweeten (1963), and other sources are noted.

Model A

The first model is derived from the economic theory of the firm as presented in the preceding sections. The amount demanded of fertilizer, for example, is dependent upon the prices of fertilizer, its substitutes (e.g., land and labor), and the final product price, ceteris paribus. Model A specifies the amount of fertilizer demanded in period t, Q_{ft}, as a function of input/output price ratios:

$$Q_{ft} = a_0 + a_1(P_f/P_R)_t + a_2(P_F/P_R)_t \tag{2.3}$$

where $(P_f/P_R)_t$ and $(P_F/P_R)_t$ are the ratios of fertilizer and farmland prices, respectively, to final product price in period t and a_0, a_1, and a_2 are function parameters.

Other substitutes can be included in a specification such as Model A; the model is not limited to just one substitute. Also, it may be desirable to add complements to the model specification. For example, the price of a more expensive, fertilizer-responsive crop variety may significantly affect fertilizer demand as it fluctuates relative to product price.

Model B

An alternative specification of Model A yields Model B. The basic elements are not changed but the arrangement is changed. Model B is specified as:

$$Q_{ft} = a'_0 + a'_1(P_f/P_R)_t + a'_2(P_f/P_F) \qquad (2.4)$$

Fertilizer demand is considered a function of its own price relative to product price and its substitute's price. Model B brings the interplay between input and substitute in directly with the inclusion of the input-substitute price ratio. The inclusion of complements and substitutes is desirable and appropriate for Model B as for Model A.

Model C

Relative prices or price ratios are not appropriate when the permanent portion of one price is perceived to be larger than the permanent portion of another price. Thus, a proportionately equal price change resulting in a constant price ratio may be perceived as a changing price ratio. To capture this effect, Model C is formulated as:

$$Q_{ft} = b_0 + b_1 P_{ft} + b_2 P_{Ft} + P_{Rt} \tag{2.5}$$

Model C may be useful in the analysis of machinery demand. Given the history of crop price fluctuations and the relative stability of machinery prices, farmers will perceive a larger portion of a change in machinery prices as being permanent than a change in crop prices. Thus, the response to machinery price changes will be greater than to crop price changes. Model C can capture this difference in response but Models A and B are locked into ratio analysis.

Model D

The naive model, Model D, is important in investment analysis for expectations and as a benchmark in model performance comparison. Model D is specified here with expected net farm income in period t, Y^*_{Ft}, as a function of past incomes, where Y_{ft-i} is the net farm income in period t-i:

$$Y^*_{Ft} = a + b_1 Y_{Ft-1} + b_2 Y_{Ft-2} + \ldots \tag{2.6}$$

The linear form is used but the estimated parameters are not forced to be declining or increasing over time. Also, no assumptions are made of the magnitudes of the parameters nor the number of lags. However, statistical limitations such as the need for degrees of freedom and insignificant and (or) unstable parameter estimates do limit the number of lags that may be used appropriately.

Model E

A more restrictive version of Model D can be used to estimate expectations of variables to be used in other equations. A priori assumptions may place restrictions on the value and distribution of the b's in (2.6). Recent years may influence expectations the greatest with the influence of later years declining at a linear rate. Model E is formulated using these conditions. With net farm income as an example over n years, Model E is:

$$Y^*_{Ft} = a + b \frac{nY_{Ft-1} + (n-1)Y_{Ft-2} + \cdot \cdot \cdot + Y_{Ft-n}}{\sum\limits_{i=0}^{n} (n-i)} \tag{2.7}$$

When n = 3,

$$Y^*_{Ft} = a + b \frac{3Y_{Ft-1} + 2Y_{Ft-2} + Y_{Ft-3}}{6} \tag{2.8}$$

The value of n can be varied to find its value which minimizes the mean square error. Alternative specifications can be made to change the declining impact and (or) the linear assumption.

Model F

Assuming no increasing or decreasing impact of past income, the simple average of n incomes can be used. In Model F the past n incomes have an equal impact on the expected income in period t:

$$Y^*_{Ft} = a + b\,\frac{Y_{Ft-1} + Y_{Ft-2} + \cdot\cdot\cdot + Y_{Ft-n}}{n} \tag{2.9}$$

When n = 3,

$$Y^*_{Ft} = a + b\,\frac{Y_{Ft-1} + Y_{Ft-2} + Y_{Ft-3}}{3} \tag{2.10}$$

The declining impact of incomes as in Model E is appealing but a situation may exist where equal impacts as in Model F are more accurate. In farming, where risk and uncertainty play a larger role than many other industries, a sudden change in net income may be looked upon as a one-time occurrence and not as a beginning of a trend. Hence, Model F which responds slower to income changes may explain changes in investment and demand better than Model E. The choice between the two models is necessarily an empirical one.

Model G

Several variables discussed previously can be included in the same model. Model G considers the demand quantity or stock of farm machinery a function of expected income; the ratio of machinery price to prices received by farmers, P_M/P_R; time, T; and a residual error, u:

$$Q_{Mt} = a + bY^*_{Ft} + c(P_M/P_R)_t + dT + u_t \tag{2.11}$$

Equation (2.6), Model D, is substituted into (2.11) to form Model G. Thus, the advantage of Model G is that of Model D; the coefficients on past net incomes are not restricted in sign or magnitude. But, the disadvantage is the same; the length of the lag is unknown without empirical experimentation.

By empirical evidence the lag in incomes may be limited to three periods (i.e., Y_{Ft-1} to Y_{Ft-3}). This does not say that Y_{Ft-4} and earlier do not exhibit influence on machinery purchases, but due to statistical considerations of degrees of freedom or coefficient instability, the earlier incomes are excluded. If this is the case, the problem of autocorrelation in the error terms arises. The unexplained influence of excluded income terms is included in the error term, u, causing u to be positively autocorrelated and not randomly distributed as required for ordinary least squares coefficient estimates to be efficient.

To overcome the degrees of freedom problem, restrictions can be placed on the coefficients of lagged incomes. This would allow an aggregation of income terms. Models E and F are examples of the type of restrictions that may be placed upon the coefficients. Autocorrelation in the error term may be present with this restriction and would need to be corrected.

Model H

In the first section of this chapter the similarities between equity and net farm income and their impacts upon investments were discussed. Model H substitutes E for Y^*_F in (2.11):

$$Q_{Mt} = a + bE_t + c(P_M/P_R)_t + dT + u_t \tag{2.12}$$

The chief advantage of Model H is the need of only one variable, E, to be included as an indicator of past incomes. But some information is lost concerning the b_i values in (2.6). Also, there is some doubt on the reliability of E as an indicator of past net income when varying portions of those incomes are used for family consumption. However, the equity ratio is used often by farmers and credit institutions as an indicator of the current financial position and thus, loan repayment capacity. It is an indicator of its own worth.

Model I

Another expectation model is developed using the expected change in income for the current year as proportional to the error made in estimating income last year:

$$Y^*_{Ft} - Y^*_{Ft-1} = e(Y_{Ft-1} - Y^*_{Ft-1}) \tag{2.13}$$

where e is the expectation coefficient and usually is assumed to lie between zero and positive one. This relationship, (2.13), and (2.11) are used by Nerlove (1958) to formulate an investment model. Equation (2.11) is solved for Y^*_{Ft} and Y^*_{Ft-1} which are substituted into (2.13). Model I is formulated by solving for Q_{Mt}:

$$\begin{aligned} Q_{Mt} = {} & ae + beY_{Ft-1} + c(P_M/P_R)t - (1 - e)c(P_M/P_R)_{t-1} \\ & + deT + (1 - e)Q_{Mt-1} + u_t - (1 - e)u_{t-1} \end{aligned} \tag{2.14}$$

Autocorrelation will most likely be present in (2.14) and must be accounted for in the estimation process.

Two estimates of the expectation coefficient are available, so the lagged price variable is omitted at times and Model I is approximated. The assumption that e lies between zero and one implies that the impact of earlier prices decreases but never reaches zero. The coefficients of (2.11) can be estimated from the estimates in (2.14).

Model J

Several of the previous models have assumed farmers make decisions based on expected income. Model J is an adjustment model. Adjustment models assume that farmers are fairly certain of decision variable values but adjust slowly to changes due to psychological, institutional, technological, and other reasons. For most resources, adjustment to changes is quite rapid at first but then slows with adjustments becoming quite small as the equilibrium level is reached. This follows in that investment decisions are based on operating environment changes but not all planned investment is done in the current period; this is used in neoclassical investment theory.

For Model J, we differ from neoclassical theory some and let the actual adjustments in purchases in the current year be a constant, g, rather than a changing proportion, of the difference between the desired or equilibrium level of purchases in the current year and the actual purchases during the past year:

$$Q_{Mt} - Q_{Mt-1} = g\ (Q^*_{Mt} - Q_{Mt-1}) \tag{2.15}$$

Nerlove (1958) uses this relationship to develop a demand model. The equilibrium level of demand is defined as:

$$Q^*_{Mt} = a + bY_{Ft-1} + c(P_M/P_R)_t + dT + u_t \tag{2.16}$$

Substituting (2.16) into (2.15) and solving for Q_{Mt}, Model J is formulated:

$$Q_{Mt} = ag + bgY_{Ft-1} + cg(P_M/P_R)_t + dgT +$$

$$(1 - g)Q_{Mt-1} + gu_t \tag{2.17}$$

The adjustment coefficient, g, is calculated from the coefficient for the lagged quantity. The price and income coefficients are short-run as estimated in (2.17) and are changed to the long-run coefficients in (2.16) by dividing by the adjustment coefficient, g.

Model J, an adjustment model, is similar to Model I, an expectation model, but the error structure is less complicated in Model J. If expectations and adjustments are both essential in the investment equation, expectations of Y_{Ft-1} can be obtained as in (2.6), (2.7), or (2.9) and inserted into Model J. Model J can be used for either investment level or stock level by using the appropriate variables.

Model K

Adjustments to a stock level can be described in a way similar to (2.15). The actual adjustment in machinery inventories in the current year is some proportion, g, of the desired or equilibrium change in inventories or stocks:

$$S_{Mt+1} - S_{Mt} = g(S^*_{Mt+1} - S_{Mt}) \tag{2.18}$$

where S_{Mt} is the machinery stock on January 1 of year t and S^*_{Mt+1} is the desired or long-run equilibrium stock of machinery on January 1 of year t+1. Depreciation is assumed to be a constant proportion, h, of beginning year stock; thus, ending year stock equals current investment plus undepreciated beginning year stock:

$$S_{Mt+1} = Q_{Mt} + (1 - h)S_{Mt} \tag{2.19}$$

By rewriting (2.19) we obtain the expression for current machinery investment:

$$Q_{Mt} = (S_{Mt+1} - S_{Mt}) + hS_{Mt} \tag{2.20}$$

Mirroring (2.16), the desired level of stocks is:

$$S^*_{Mt+1} = a + bY_{Ft-1} + c(P_M/P_R)_t + dT + u_t \tag{2.21}$$

By substituting (2.21) into (2.18) and the resulting expression into (2.20), the investment model K is formed:

$$Q_{Mt} = ag + bgY_{Ft-1} + cg(P_M/P_R)_t + dgT + (h-g)S_{Mt} + gu_t \qquad (2.22)$$

The disadvantage of Model K is that the long-run coefficients of (2.21) cannot be determined from the estimates of (2.22) without exogenous data because the separate values of h and g are not known. There are two alternatives to allow estimation of these long-run coefficients. The estimate of g, the adjustment coefficient, in (2.17) may be used in (2.22) even though the two adjustment coefficients may not be directly comparable. An alternative is to have an estimate of the machinery depreciation rate, h, from another source and to calculate g in (2.22) from the lagged stock coefficient.

Model K does have the advantage of using machinery stock as a variable to explain annual investment in machinery. Annual investment is much more volatile than and is dependent upon machinery stock.

Model L

To include risk in the investment analyses, the procedures developed by Just (1974) are adapted slightly. For investment analysis the variance of the return to investment may be larger and, thus, more important in farmers' decisions than the variance in investment price. Using net farm income as a proxy for investment return, risk is measured as the variance between expected and actual net income:

$$V_t = \emptyset \sum_{k=0}^{\infty} (1 - \emptyset)^k (Y_{Ft-k-1} - Y^*_{Ft-k-1})^2 \qquad (2.23)$$

where V_t is a weighted aggregate of past observations on risk, Y_{Ft} and Y^*_{Ft} are actual and expected net farm income in year t, respectively, and $\emptyset$ is a scalar parameter. The measure of expected income is done in a manner such as (2.6), (2.7), and (2.9); the resulting variance may be calculated by these methods also.

This measure of income variance incorporates several items. The unexpected price changes and thus changes in actual income are captured. The changes in total production and productivity due to weather are also captured. External forces such as the export market and their impacts on changing actual incomes are also included. These variables are not included in the analysis explicitly but are included with this risk measure implicitly.

Rewriting (2.16) to include a risk measure results in:

$$Q^*_{Mt} = a + bY_{Ft-1} + c(P_M/P_R)_t + dT + eV_{t-1} + u_t \qquad (2.24)$$

where e is the long-run coefficient on income variance. By including V_{t-1} in (2.24) and developing models analogous to (2.17), (2.22), and others, the short-run and long-run impacts of risk can be estimated.

Earlier in this section, the prices of inputs and products were shown to determine the profit-maximizing levels of input usage. Deviations from these optimal levels are caused by other factors. High income may cause investment to be greater than the optimal levels; low income may cause investment to be lower than the optimal level. The measure of risk in the income variation term developed here estimates another force that may cause farmers to invest in or utilize inputs below the optimal level.

These models just developed exemplify the specific models that will be used in later chapters in national resource demand analysis. Some models are input specific and others can be adapted to several inputs. They include expectation and adjustment models which can be used as single-equation models and models within a system. Following chapters will use this background and the statistical procedures in the next chapter to analyze specific investment models. Actual models used may use these models directly or may estimate these models.

CHAPTER III. STATISTICAL PROCEDURES AND CONSIDERATIONS

Econometric analysis rests not only on the correct specification of the economic model but also on the selection of the appropriate statistical procedures. The appropriateness of statistical procedures is measured by the goals of the analysis and by problems and conditions encountered in the analysis. These procedures are discussed in this chapter. Short sections on data reliability, confidence levels in estimation results, and forecasting are included at the end of the chapter.

Although the demand for machinery is not expected to be independent of the demand for labor, for example, the independence of models is assumed in the first part of this chapter to ease the discussion of procedures and potential problems. Later the more appropriate procedure of system analysis is presented.

Single Equation Estimation

A typical econometric method of quantifying the relationship between a dependent variable, Y, and explanatory variables, X_1, X_2, . . ., X_k, is to assume a relationship that is linear in the coefficients:

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \cdots + \beta_k X_{kt} + u_t$$

or in matrix form:

$$y = X\beta + u \tag{3.1}$$

where the β_i's are the parameters of the model, u_t is the error term associated with Y_t, and the subscript t denotes the tth observation in T observations.

The model in (3.1) is written with the following assumptions. (1) The relationship between Y and the X_i's is linear and correctly specified. That is, it includes all relevant independent variables but contains no irrelevant variables. (2) The X_i's are nonstochastic variables whose values are fixed. That is, the researcher knows the values of the X_i's with no measurement error and finds these values in repeated samplings. Thus, the only source of variation in the model is Y. (3) The error terms have expected values of zero, constant variance for all observations, and expected covariances of zero between observations. This can be written in matrix form as:

$$E(u) = 0 \tag{3.2}$$

and

$$E(uu') = \sigma^2 I_n \tag{3.3}$$

where I is an (nxn) identity matrix and σ^2 is the population error variance. (4) The number of observations is greater than the number of parameters to be estimated and no independent variable is a linear combination of other independent variables. In matrix notation this requires $X'X$ to be of rank k which allows the inverse of $X'X$ to exist.

Ordinary least squares (OLS) estimation

The basic estimation procedure for the model just described and which Pindyck and Rubinfeld (1976) refer to as the classical linear regression model is ordinary least squares. This procedure minimizes the sum of squared residuals of the estimated model. Using matrix notation, the OLS estimate of β which minimizes $e'e$, the sum of squared residuals, is

$$\hat{\beta} = (X'X)^{-1}X'y \tag{3.4}$$

where $y = X\hat{\beta} + e$ and e is a vector of n residuals. Since X remains fixed it can be shown that $\hat{\beta}$ is unbiased:

$$E\,(\hat{\beta}) = \beta$$

The variance of $\hat{\beta}$ is given by

$$\mathrm{Var}\,(\hat{\beta}) = \sigma^2(X'X)^{-1}$$

where σ^2 is the variance of the disturbance term, u, in (3.1) as stated in (3.3). The expected value of the sum of squared residuals is:

$$E(e'e) = (T - k)\sigma^2$$

Thus, the unbiased estimator of σ^2 is:

$$s^2 = \frac{e'e}{T-k} = \frac{y'y - \hat{\beta}'X'y}{T-k}$$

Ordinary least squares estimates are consistent and unbiased if the assumptions of the classical linear model hold. The next few parts explain and point out problems and corrective procedures when these assumptions are not valid.

Model specification error

Excluding relevant variables or including irrelevant variables in X may have undesirable impacts upon parameter estimation. For example, say the true model is (3.1) but the estimated model is specified as:

$$y = X_1\beta_1 + u_1 \tag{3.5}$$

where

$$X = (X_1 \ , \ X_2)$$

and

$$\beta = (\beta_1 \ , \ \beta_2)$$

Relevant variables, X_2, have been excluded. This results in biased estimates of β_1:

$$E(\hat{\beta}_1) = \beta_1 + (X_1'X_1)^{-1}X_1'X_2\beta_2$$

It can be shown that $\hat{\beta}_1$ is inconsistent as well. Estimates and projections using $\hat{\beta}_1$ would be in error; the magnitude of the error would depend upon the degree of correlation between X_1 and X_2 and the importance of the variables in X_2. The variation in y explained by X_2 would be absorbed by e_1 in the estimation of β_1; this would result in an upward bias in s^2 and wider confidence intervals for each specific confidence level.

Again, suppose the true model is (3.1) and the estimated model is specified as

$$y = X_1\beta_1 + u_1$$

which is the same as (3.5) except that

$$X_1 = (X \;,\; X_2)$$

Irrelevant variables have been included along with all relevant variables. For this misspecification Intriligator (1978, p. 188-189) shows that the estimates of β for the true model are unbiased and consistent. The variance of $\hat{\beta}$ is unbiased also. However, due to the loss of degrees of freedom by including irrelevant variables, the sample variances of the estimated coefficients will tend to increase affecting tests of significance and confidence intervals.

Other statistical problems

Other assumptions of the classical linear model may not be valid in certain instances. Stochastic independent variables and variables measured with error cause problems because variation within the model is no longer associated with the dependent variable solely; instrumental variables or two-stage least-squares procedures may be used to overcome these problems. Autocorrelation of the error terms causes OLS estimates to be inefficient; this can be removed by using generalized least-squares or autoregressive least-squares, or by estimating the correlation coefficient(s), transforming the original data, and re-estimating the model. Highly correlated independent variables may cause their true separate impacts on the dependent variable to be lost.

This is not an exhaustive list of problems or procedures. The problems mentioned are ones expected in this analysis. The theory of and methods for these procedures are dealt with in many econometric books and so is not dealt with explicitly here. Johnston (1972), Intriligator (1978), and Pindyck and Rubinfeld (1976) are offered as examples of good, intermediate-level reference books.

Up to now we have been assuming independence of equations. But as in the machinery-labor example mentioned at the beginning of this chapter, independence may not always be a correct assumption. In the next section the method utilized for estimation of one equation within a system is presented.

Simultaneous Equations Estimation

Assuming that a relationship is independent of other relationships, when in fact there does exist an interdependency, results in biased and inconsistent estimates. In the analysis of agricultural resource structure interdependencies are evident; thus, estimation techniques appropriate to this condition must be selected.

Once the need for a systems approach has been shown, there is still a choice between procedures. Intriligator (1978) and Johnston (1972) discuss several Monte Carlo studies of small samples and conclude from them that two-stage least-squares (2SLS) shows the best characteristics in terms of both bias and mean square error but is quite sensitive to high degrees of correlation among the independent variables. These conclusions are based on the testing conditions of manufactured data. As Intriligator (1978, p. 419) points out, in actual econometric studies the data are often inaccurate to such a degree and (or) the correct specification of the model is so uncertain that the relatively small differences between estimators tend to disappear.

Fuller's (1977b) modified limited information maximum likelihood estimator (MLIML) is not among the estimators compared by Intriligator (1978) and Johnston (1972). Fuller shows the MLIML estimator to have equal or lower mean square error than the fixed k-class estimator using an arbitrarily set bias for both; this result is for the asymptotic case. Fuller's modification also allows the researcher to choose between selecting estimates which are nearly unbiased or estimated which minimize the mean square error; this is true in the asymptotic case and not necessarily true for small samples.

When selecting the statistical procedure appropriate to this study, several factors were considered. While the limited information maximum likelihood estimator is sensitive to model misspecification in the Monte Carlo studies, it is not as sensitive as 2SLS to correlations between independent variables. The MLIML estimator is shown to dominate other k-class estimators with equal or lower mean square error (with the same, arbitrary bias) in the asymptotic case. For these reasons and Intriligator's comments on data inaccuracies and model specification uncertainties, the MLIML is chosen for use in this analysis.

The following subsection covers the estimation procedures of the MLIML estimator. Following that is a subsection describing a method for correcting for autocorrelation within a system.

Modified limited information maximum likelihood (MLIML) estimation

The MLIML estimator possesses finite moments and one member of the class has bias of order T^{-2} where T is the number of observations. The estimator is a member of the k-class estimators as described by Theil (1971).

The following outline of the estimation procedure for MLIML estimation follows Fuller (1977a, p. 54-56; 1977b).

The equation of interest is

$$y = \gamma_1\beta + X_1\gamma + u \tag{3.6}$$

where y is an array with Tx1 dimensions; Y_1, Txg; β, gx1; X_1, Txk; γ, kx1; and u, Tx1. The system contains an additional K-k exogenous and(or) lagged endogenous variables. The matrix of all predetermined variables is

$$X = (X_1 \ , X_2)$$

where X_2 is dimensioned Tx(K-k). For equation (3.6) to be identified K-k $\geq$ g.

The MLIML estimator is given by

$$\begin{pmatrix} \hat{\beta} \\ \\ \hat{\gamma} \end{pmatrix} = \begin{pmatrix} Y_1'Y_1 - \emptyset W_{22} & Y_1'X_1 \\ \\ X_1'Y_1 & X_1'X_1 \end{pmatrix}^{-1} \begin{pmatrix} Y_1'y - \emptyset W_{21} \\ \\ X_1'y \end{pmatrix} = \hat{H}^{-1}\hat{N} \qquad (3.7)$$

where

$$\emptyset = \hat{1} - \frac{\alpha}{T-k}$$

$\hat{1}$ is the smallest root of

$$W^* - 1W = 0,$$

$$W = Y'Y - Y'X(X'X)^{-1}X'Y$$

$$= \begin{pmatrix} W_{11} & W_{12} \\ W_{21} & W_{22} \end{pmatrix},$$

$$Y = (y \ Y_1)$$

$$W^* = Y'Y - Y'X_1(X_1'X_1)^{-1}X_1'Y.$$

The estimator of the covariance matrix of the MLIML estimator is

$$\hat{H}^{-1}s_u^2$$

where $\hat{H}^{-1}$ is from (3.7),

$$s_u^2 = \frac{1}{T-g-k}\,\hat{u}'\hat{u},$$

and

$$\hat{u} = y - Y_1\hat{\beta} - X_1\hat{\gamma}.$$

The modification comes in the inclusion of the α term; the unmodified estimator uses $\alpha = 0$. Fuller (1977b) shows that by setting $\alpha = 1$ nearly unbiased estimates can be obtained. When the objective is to test hypotheses or set approximate confidence intervals for the parameters α would be set to 1. By setting $\alpha = 4$ Fuller shows this would minimize the mean square error of the estimators due to the effect of α upon the expression for mean square error. This latter option is appropriate when predictions are desired as in this analysis. These characteristics of α hold in the asymptotic case.

These procedures outlined account for several problems of not meeting the assumptions of the classical linear model. But if the errors in (3.6) are correlated with each other, the MLIML estimates are inefficient. The procedure outlined next overcomes this problem of autocorrelation.

Correcting for autocorrelation in one equation within a system

Autocorrelation (or serial correlation) is a violation of the assumption for the classical linear model that the disturbance terms are uncorrelated with each other. When autocorrelation is present least squares estimates are still unbiased and consistent but do not have minimum variance. There also will be a bias in the error variance estimate causing the tests of significance to be invalid.

Autocorrelation may occur for several reasons. Time series data as used here are susceptible due to slowly changing variables excluded from the model but having an impact upon the dependent variable. Aggregation of data as done for the data used in this analysis may cause autocorrelation. Misspecification can cause autocorrelation as well, especially excluding relevant variables.

Estimating an equation within a system will not correct autocorrelation implicitly. The procedure given here as developed by Fuller (1978) utilizes a one step Gauss-Newton procedure for estimating an equation within a system when the errors are assumed to satisfy a first-order autoregressive process.

Following Fuller's (1978) notation, the equation to be estimated is written as

$$y_1 = Y_2\beta + X_1\gamma_1 + Y_{3,-1}\,\gamma_3 + u_1 \tag{3.8}$$

where we assume

$$u_{t1} = \rho_1 u_{t-1,1} + \varepsilon_t$$

$$|\rho_1| < 1$$

$$\varepsilon_t \sim NID(0, \sigma^2)$$

and that ε_t is independent of the lagged values of all endogenous variables in the system. The vector y_1 contains the endogenous variable to be explained. The matrix Y_2 contains the endogenous variables other than y_1 in the equation. X_1 and $Y_{3, -1}$ are the predetermined variables in the equation; X_1 being a matrix of exogenous variables and $Y_{e, -1}$ being a matrix of lagged endogenous variables. Other predetermined variables are assumed to be in the system but not the specific equation and of sufficient number to identify (3.8). X_2 is the matrix of exogenous variables in the system but not (3.8); $Y_{4, -1}$ is the matrix of lagged endogenous variables in the system but not (3.8).

With other assumptions of the behavior and makeup of the data, Fuller outlines a five-step procedure for estimating (3.8). These are condensed to three steps:

1. Obtain preliminary estimates of β, γ_1, and γ_3 from (3.8) using only exogenous and lagged exogenous variables to obtain estimates of $\hat{Y}_2$ and $\hat{Y}_{3, -1}$. This step may use the modified limited information maximum likelihood estimator or two stage least squares.

2. Estimate ρ_1 by

$$\hat{\rho}_1 = \frac{\sum_{t=2}^{n} \hat{u}_{t1}\hat{u}_{t-1,1}}{\sum_{t=2}^{n} \hat{u}_{t-1,1}^2}$$

where $\hat{u}_{t1}$ is estimated using $\hat{\beta}$. $\hat{\gamma}_1$, and $\hat{\gamma}_3$ from the first step and the original data (not $\hat{Y}_2$ and $\hat{Y}_{3,-1}$). This estimate of ρ_1 is used to transform the original data in the usual manner:

$$w_{1t} = \begin{cases} \sqrt{1 - \hat{\rho}_1^2}\, y_{1t} & , t = 1 \\ y_{1t} - \hat{\rho}_1 y_{1,\, t-1} & , t = 2, 3, \ldots, T \end{cases}$$

The transformed matrices for y_1, X_1, X_2, Y_2, $Y_{3,\,-1}$, and $Y_{4,\,-1}$ are denoted by w_1, H_1, H_2, W_2, $W_{3,\,-1}$, and $W_{4,\,-1}$, respectively.

3. Using the transformed data and the Taylor series approximation for the Gauss-Newton procedure, equation (3.8) is rewritten as

$$w_1 \doteq W_2\beta + H_1\gamma_1 + W_{3,\,-1}\gamma_3 + \hat{u}_{1,\,-1}\Delta\rho_1 + \varepsilon + \text{Remainder} \qquad (3.9)$$

where $\hat{u}_{1,\,-1}$ is a vector with $\hat{u}_{t-1,\,1}$ as the tth element for t = 2, 3, . . ., T and $\hat{u}_{0,\,1} = 0$. The parameters of equation (3.9) are then estimated by any of the single equation methods; presumably the same method as used in step 1. In this step the predetermined variables may now include H_1, H_2, $W_{3,\,-1}$, $W_{4,\,-1}$, and $\hat{u}_{1,\,-1}$.

Fuller points out that since the remainder in equation (3.9) is a function of the error on $\hat{\beta}$, $\hat{\gamma}_1$, and $\hat{\gamma}_3$, the estimates of (3.9) are consistent. If the estimated $\Delta\rho_1$ in (3.9) is too large relative to $\hat{\rho}_1$ from step 2 the procedure may be iterated. This method will be quite efficient if all equations in the system have similar autocorrelation structure.

The procedures discussed in this chapter include those appropriate to this analysis. A few additional comments on some other statistical considerations are needed.

Data Reliability and Confidence Levels

Intriligator's (1978) observation noted earlier that in actual analysis the error in the observations makes the differences between estimators relatively small holds true for this study. The methods of collection and analysis of the data used in this study are presented in several volumes of a U.S. Department of Agriculture handbook (1969a, 1969b, 1970, 1971a, 1971b). In general, the data are described as having some error but being fairly accurate (i.e., they are in a small ballpark).

The indices of prices received and paid by farmers depend in part upon questionnaires mailed to samples of farmers and others closely connected to agriculture. Error occurs due to the sampling process, misconceptions and(or) misinformation on the part of respondents, and misinterpretation of the questions. While statistical tests show some difference between prices from the mail survey and those gathered by direct contact, the U.S. Department of Agriculture (1970, p. 10) says that the differences are not large enough to doubt the validity of mail survey data. However, that does not mean that the data is without error. Nonresponse may introduce a bias; and response errors due to supplying the wrong information in the form of entries priced in the wrong quantity unit and list prices reported instead of actual prices. The U.S. Department of Agriculture has editing and guides to reduce some of the error from these sources.

Gross farm income is the most accurate of the income measures; it is calculated largely from cash marketing receipts. Production expenses are derived from Census of Agriculture "benchmarks" and survey data for years in between but the surveys are not as complete in coverage as the census is. Net farm income is calculated as the residual of gross farm income after production expenses are accounted for and so captures the error from both measures. Preliminary estimates have the greatest error, but as further data is obtained and estimates are updated, error decreases (U.S. Department of Agriculture, 1969b).

"The Balance Sheet of the Farming Sector" (e.g., Evans and Simunek, 1978) includes farm assets and debts of both farm operators and non-farm landlords. Thus, the U.S. Department of Agriculture (1971b) says it is not a balance sheet of any specific group or industry. For the purposes of this study this aggregation does not affect the results since the ratio of assets to debt for agriculture in total is desired. Error is introduced because unreported assets (e.g., checking account balances) and debts (e.g., accounts at local stores) are estimated with little supporting data. The exclusion of nonfarm net worth of farm operators introduces error to the degree with which this net worth affects operators' decisions.

Besides reporting errors the estimates of farm employment include only those employed by the farm operator. Bias enters when the amount of custom services increases and labor is included in custom charges but not in the employment count. The estimated level includes both full- and part-time workers and duplication does occur due to workers working on two or more farms.

Many of these statistical series are not valid as measures of absolute levels of the specific categories. However, the series can be used for estimates of annual changes and indicative of trends. This condition does not hamper the analysis of this study except that any projections and forecasts must be viewed as indicative and not absolute.

Since there is no measure of the errors associated with these statistics, there can be no statistical impact calculated. That is, with no estimated variance between actual and estimated levels of the data, there can be no estimated impact of this error upon structural elements and forecasts. However, we do know that the error exists and so we expect the results to be affected to some degree and we make our conclusions with this potential error in mind.

Forecasting

Econometric models are developed and estimated for one or both of two reasons. The first is to estimate the structural coefficients of the relationships within the model; the procedures for this reason are described in the earlier sections of this chapter. The second reason is to forecast or predict future levels of the endogenous variables; the procedures for this reason are presented in this last section.

To forecast endogenous variable levels, the structural equations may be estimated first and the structural parameter estimates used in prediction. Another method is to estimate the reduced form equations and obtain predictions from these estimates. Information regarding the structural coefficients is not available if this latter method is followed.

Let us consider the model of the complete system in which (3.1) is incorporated. The structural model written in matrix form and following Johnston's (1972) notation is

$$\beta y_t + \Gamma X_t = u_t \tag{3.10}$$

where β is a (GXG) matrix of coefficients of current endogenous variables, Γ is a (GXK) matrix of coefficients of predetermined variables, and y_t, X_t, and u_t are column vectors of G, K, and G elements respectively. Assuming the β matrix is nonsingular, the reduced form model is

$$y_t = \pi X_t + v_t \tag{3.11}$$

where π is a (GXK) matrix of reduced form coefficients and v_t is a column vector of G reduced form disturbances:

$$\pi = -\beta^{-1}\Gamma$$

$$v_t = \beta^{-1}u_t$$

Point forecasts from this system are obtained by substituting estimates of future values of predetermined variables into the estimated reduced form equation:

$$\hat{y}_f = \hat{\pi}x_f \tag{3.12}$$

where x_f denotes the vector of forecast values for the predetermined variables, $\hat{\pi}$ is the matrix of estimated reduced form coefficients, and $\hat{y}_f$ is the column vector of forecast values of the endogenous variables.

The matrix $\hat{\pi}$ is estimated by two methods. If the model specification is correct, estimating $\hat{\pi}$ from the structural coefficients,

$$\hat{\pi} = -\hat{\beta}^{-1}\hat{\Gamma} \tag{3.13}$$

is preferable. However, if the model specification is incorrect, estimating $\hat{\pi}$ from the reduced form equations directly may be more desirable and is the procedure used in this analysis.

In this chapter several statistical considerations are covered. The problems encountered when the assumptions of the classical linear model are not valid are discussed. The selection of the method of simultaneous equation estimation is made and the procedure presented. The reliability of the data and the subsequent impact upon estimate confidence are covered. Finally, the procedures for forecasting are presented.

In following chapters, these procedures are used to estimate the structural coefficients of demand for and investment in agricultural resources. Projections of the mix or structure of resources in 1990 are made in Chapter VII.

CHAPTER IV. DEMAND FOR MACHINERY AND BUILDING AND LAND IMPROVEMENTS

Farm machinery and building and land improvements unlike land itself are produced every year by the manufacturing and construction sectors and sold to the farm sector of the U.S. Demand for these inputs differs from demand for other agricultural resources. Machinery and building and land improvements are not used up in one production period as are operating inputs; they are not hired for certain time periods or jobs as is labor. The full ownership rights are purchased and the machinery and improvements are expected to be used for several years. Thus, factors from a longer period are expected to influence machinery and building demand.

Farm machinery includes tractors, trucks, and automobiles for farm use; planting, harvesting, and tillage equipment; and other mechanical equipment used in the farm business. Building and land improvements include new construction, additions, and major improvements of service buildings, other structures, fences, windmills, wells, dams, ponds, terraces, drainage ditches, tile lines, other soil conservation facilities, and dwellings not occupied by farm operators.

Although they are expected to be used for several years, machinery and buildings and land improvements are not homogenous over time. New technologies and practices have changed the machines and buildings demanded and supplied. Tractors have become larger. Mechanical corn pickers largely have been replaced by self-propelled combines. Mechanical harvestors have replaced human labor in several crops. Grain bins have given way to farm grain handling systems sometimes larger than local elevators of past years. Livestock confinement systems have changed the traditional set of farm buildings. Larger operations and equipment have changed the water demands on wells and the types of terraces built. Even government intervention has altered machinery and building demand (e.g., waste containment and treatment systems). This is why total expenditures are analyzed in this study instead of individual types of machinery and buildings.

Machinery and improvement expenditures have increased in real terms since 1945 (Table 4.1). Expenditures for improvements have increased at a fairly steady rate while machinery expenditures have not. Expenditures for improvements in 1977 are 161 percent greater than the level in 1945. Machinery expenditures in 1977 are 30 percent greater than the level in 1945 but the 1977 level is the lowest level of machinery expenditures since 1962 when it was $3,687 million 1967 dollars. The expenditures in 1967 dollars are calculated by dividing current dollar expenditures by the appropriate price index in which the value for 1967 equals 1.0.

These changes in expenditures have occurred for many reasons;

Table 4.1. Farmers' expenditures for all machinery and building and land improvements, 1945-1977, selected years[a]

Year	All farm machinery[b]	All farm improvements[c]
	(million 1967 dollars)	
1945	2,993	754
1950	5,073	1,143
1955	3,938	980
1960	3,378	1,238
1965	4,493	1,430
1970	4,270	1,659
1975	4,412	1,811
1977	3,896	1,965

[a]Calculated from data in (U.S. Department of Agriculture, Economics, Statistics, and Cooperative Service, 1978, p. 47)

[b]Includes farm share of all motor vehicles and non-motorized farm machinery.

[c]Includes service buildings, other structures, fences, windmills, and land improvements but excludes operators' dwellings.

price is one of them. Except for the early 1970's when crop prices rose considerably, the price of machinery has risen relative to all prices received by farmers (Figure 4.1). Since 1945 the machinery price to prices received ratio has increased the most of those in (Figure 4.1). The price of machinery relative to the farm wage rate has fallen steadily since 1950 until the last few years. The farm wage rate has increased also relative to all prices received. The price of fuel and oil which had been quite steady for many years now appears to be rising relative to all prices received. All the price ratios in Figure 4.1 are higher in 1977 than in 1945.

The price of building and fencing materials has risen fairly steadily since 1945 relative to all prices received by farmers (Figure 4.2). The per acre value of farmland relative to all prices received has increased the most of the price ratios in (Figure 4.2). The relative farm wage rate has increased at a fairly constant rate. The price of fuel and oil has remained the steadiest but has increased also. The high commodity prices of the early 1970's overpowered any increases in resource prices.

Other variables affect machinery and building and land improvements demand besides prices. Net farm income and the variation in net farm income give indications of potential returns and net of investments. Farmers' equity ratio, acres per farm, total crop acreage, and farm stocks of machinery and buildings may also

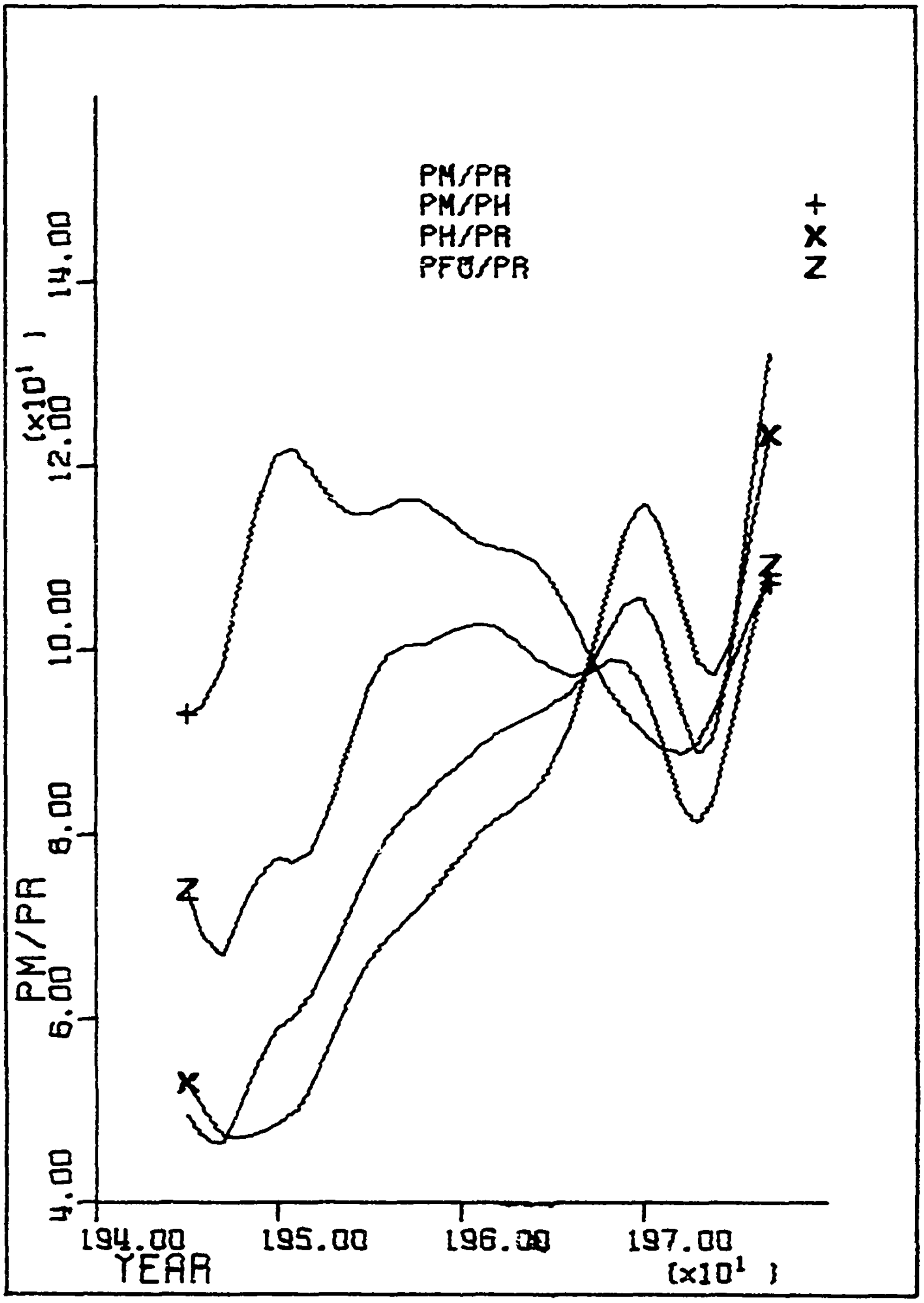

Figure 4.1. Indices of machinery prices relative to all prices received and the farm wage rate, P_M/P_R and P_M/P_H, respectively, and the farm wage rate and the price of fuel and oil relative to all prices received by farmers, P_H/P_R and P_{fo}/P_R, respectively, 1945-1977.

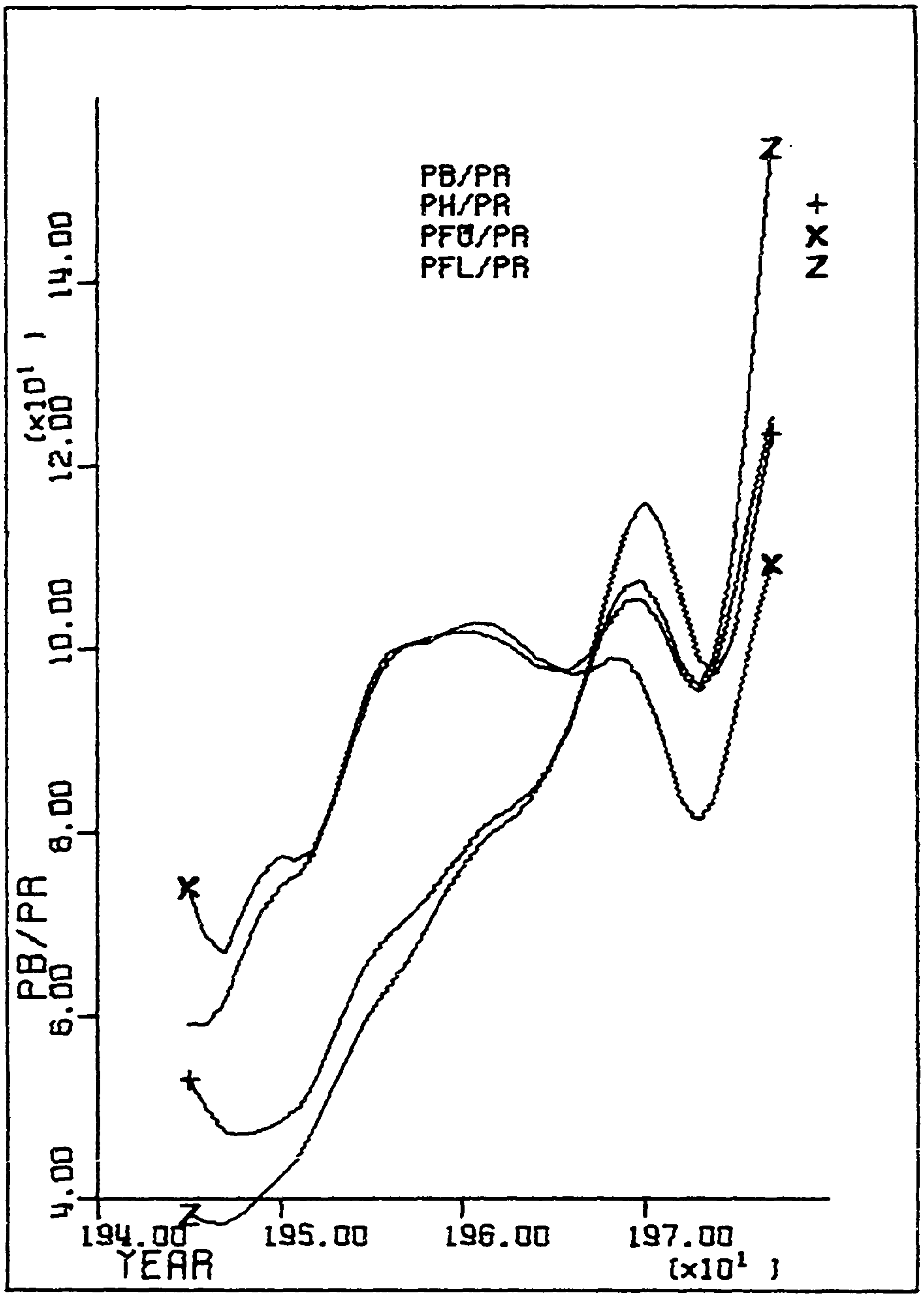

Figure 4.2. Indices of the price of building and fencing materials, the farm wage rate, the price of fuel and oil, and the value of U.S. farmland relative to all prices received by farmers, P_B/P_R, P_H/P_R, P_{fo}/P_R, and P_{FL}/P_R, respectively, 1945-1977.

affect demand for machinery and improvements.

For a better understanding of them, these relationships between demand and explanatory variables are estimated and reported in this chapter. The demand for machinery at the national level is analyzed first, then the demand for buildings and land improvements at the national level. Before the analysis is presented, the variables, models, and systems of models used are discussed.

Models of Demand for Machinery and Building and Land Improvements

Demand for machinery and demand for building and land improvements are analyzed individually in this study. The method of analysis of each is similar but some variables differ. In this section the variables, models, and systems of models used in the analysis are presented. The models explain national demand.

The separate demands for machinery and improvements are considered to be functions of their own prices and the prices of complements and substitutes, all relative to prices received; farmers' equity to debt ratio; net farm income; the variation between actual and expected net farm income; the stock of machinery or buildings; the number and size of farms; the total crop acreage; and other, slowly changing variables represented by a time variable. The reasons for including these variables in the analysis are summarized here and in Chapter II.

Farmers' demand for machinery and improvements is expected to respond inversely to changes in its own and complements prices and directly to changes in substitutes' prices. Prices received for farm products are expected to have positive effects upon labor demand. The amount of response from a certain price change depends upon the interrelationships between all resources. It is these responses this analysis measures.

Increasing net farm income indicates greater potential return to agricultural resources and thus the demand for resources increases. Variation in net farm income is expected to have a negative effect upon demand; if the variation is great, farmers' will have greater risk of low incomes and so decrease demand for machinery and improvements. The equity ratio measures financial soundness and the ability to assume debt which will allow demand to increase with better equity ratios.

In preliminary analysis, the inclusion of a dummy variable for government income support programs produced some curious results. From 1972 to 1974 there were no government programs in effect. In this period net farm income and crop prices were quite high causing investments in durable resources and purchases of other inputs to increase. Hence, the dummy variable's estimated coefficient indicates a positive effect upon demand when government programs are dropped. Since it appears to be measuring the large variances of the 1972-74 period rather than just the impact of government programs, the dummy variable is not included in the present analysis.

The stock of machinery or buildings indicates the present level of investment and the need to replenish this stock due to depreciation. Hoffmann and Heady (1962) found that machinery and building investment per acre declined as farm size grew; similar effects are expected as the number of farms change. Total crop acreage is included to test if there is a fixed or semi-fixed need per acre and not necessarily per farm.

These variables are used to delineate several demand models and are not used together in one model necessarily. From the general models discussed in Chapter II, a few models are presented here as applicable to machinery and buildings and land improvements. An adjustment model seems very reasonable to use since farmers will adjust their demand for machinery or improvements rather slowly in relation to prices, other variables, and stocks.

To simplify this discussion and to avoid duplication, let Q_I stand for Q_M, machinery expenditures, or Q_B, building and land improvements, and similarly, P_I, for the appropriate price. The desired or optimal level of demand for machinery or improvements, Q^*_I, is described as a function of their own prices and the farm wage rate relative to prices received, P_I/P_R and P_H/P_R, respectively;

national net farm income; the variation in net farm income, and slowly changing variables.

$$Q^*_{It} = a + b(P_I/P_R)_t + c(P_H/P_R)_t$$

$$+ dY_{AFt-1} + eV_{t-1} + fT + U_t \qquad (4.1)$$

Model (4.1) may be used as it is with the actual expenditure levels substituted for the desired level.

Actual adjustment in machinery and improvements demand is assumed to be a constant proportion of the difference between the desired level in the current year and the actual purchases during the past year:

$$Q_{It} - Q_{It-1} = g(Q^*_{It} - Q_{It-1}) \qquad (4.2)$$

To develop an adjustment model similar to Model J in Chapter II, (4.1) is substituted into (4.2) and solved for Q_{It}:

$$Q_{It} = ag + bg(P_I/P_R)_t + cg(P_H/P_R)_t +$$

$$dgY_{AFt-1} + egV_{t-1} + fgt +$$

$$(1-g)Q_{It-1} + gu_t \qquad (4.3)$$

Once (4.3) has been estimated, the long-run coefficients of (4.1) can be calculated using the adjustment coefficient, g, estimated from the coefficient on Q_{It-1}. Long-run and short-run elasticities are estimable.

Adjustment models of this type assume a Koyck distributed lag. The Koyck lag forces past variable values to have geometrically declining importance. For annual data as used in this study, this requirement is not too restrictive.

Alternative specifications of (4.1) can be made. The price of fuel and oil can be substituted for the farm wage rate:

$$Q^*_{It} = a + b(P_I/P_R)_t + c(P_{fo}/P_R)_t + dY_{AFt-1} + eV_{t-1} + fT + u_t \qquad (4.4)$$

or substituting the equity ratio for Y_{AF}:

$$Q_{It} = a + b(P_I/P_R)_t + c(P_H/P_R) + dE_t + eV_{t-1} + fT + u_t \qquad (4.5)$$

Adjustment models analogous to (4.3) for these desired-level models can be derived easily. Other variables can be inserted to form additional models of machinery and building and land improvements demand. In each case, adjustment models can be formulated and the long-term, as well as the short-term coefficients can be estimated.

These models of demand for machinery and building and land improvements are not assumed to be independent of other resource markets. Thus, each model is estimated within a system of markets. The system is adjusted as needed for each model. The basic system for machinery demand is described in equations (4.6) through (4.13).

$$Q_{Mt} = f\left((P_M/P_R)_t,\ (P_H/P_R)_t,\ A'_t,\ Y_{AFt-1},\ V_{t-1},\ T\right) \qquad (4.6)$$

$$(P_M/P_R)_t = f\left((P_H/P_R)_t,\ (P_H/P_R)_{t-1},\ (P_{fo}/P_R)_t,\ P_{Nt},\ T,\ (P_M/P_R)_{t-1}\right) \qquad (4.7)$$

$$(P_H/P_R)_t = f\left(Q_{Ht},\ T,\ (P_H/P_R)_{t-1}\right) \qquad (4.8)$$

$$Q_{Ht} = f\left((P_H/P_R)_t,\ (P_{fo}/P_R)_t,\ A'_t,\ T\right) \qquad (4.9)$$

$$(P_{fo}/P_R)_t = f\left(Q_{fot},\ T,\ (P_{fo}/P_R)_{t-1}\right) \qquad (4.10)$$

$$Q_{fot} = f\left((P_{fo}/P_R)_t,\ (P_M/P_R)_t,\ (P_H/P_R)_t,\ S_{Mt},\ V_{t-1},\ T\right) \qquad (4.11)$$

$$A'_t = f\left((P_{FL}/P_R)_t,\ (P_M/P_R)_{t-1},\ T,\ A'_{t-1}\right) \qquad (4.12)$$

$$(P_{FL}/P_R)_t = f\left((P_M/P_R)_t,\ (P_H/P_R)_t,\ E_t,\ T\right) \qquad (4.13)$$

The basic system for the demand for building and land improvements is described in equations (4.14) through (4.24).

$$Q_{Bt} = f\left((P_B/P_R)_t,\ (P_{fo}/P_R)_t,\ (P_{FL}/P_R)_t,\ Y_{AFt-1},\ S_{Bt},\ T\right) \qquad (4.14)$$

$$(P_B/P_R)_t = f(Q_{Bt-1}, P_{ISt}, (P_B/P_R)_{t-1}) \tag{4.15}$$

$$(P_{fo}/P_R)_t = f(Q_{fot-1}, (P_e/P_R)_t, T) \tag{4.16}$$

$$Q_{fot} = f((P_{fo}/P_R)_t, (P_M/P_R)_t, (P_H/P_R)_t, A'_t, Y_{AFt-1}, V_{t-1}, T, Q_{fot-1}) \tag{4.17}$$

$$(P_e/P_R)_t = f(Q_{et-1}, T) \tag{4.18}$$

$$Q_{et} = f((P_e/P_R)_t, A'_t, Y_{AFt-1}, V_{t-1}, T) \tag{4.19}$$

$$A'_t = f(P_{FL}/P_R)_{t-1}, (P_H/P_R)_{t-1}, T) \tag{4.20}$$

$$(P_{FL}/P_R)_t = f((P_M/P_R)_t, (P_H/P_R)_t, E_t, T) \tag{4.21}$$

$$(P_H/P_R)_t = f(Q_{Ht}, T, (P_H/P_R)_{t-1}) \tag{4.22}$$

$$Q_{Ht} = f((P_H/P_R)_t, (P_{fo}/P_R)_t, A'_t, T) \tag{4.23}$$

$$(P_M/P_R)_t = f((P_H/P_R)_t, (P_H/P_R)_{t-1}, (P_{fo}/P_R)_t, P_{Nt}, T, (P_M/P_R)_{t-1}) \tag{4.24}$$

The endogenous variables used in the above and later models are listed and defined below.

A' = the national average number of acres per farm in the U.S. on January 1 of the current year

N = the number of farms in the U.S. on January 1 of the current year

P_B = the index of the national average price of building and fencing materials

P_e = the index of the national average price of electricity on farms

P_{FL} = the index of the average per acre value of all U.S. farmland

P_{fo} = the index of the national average price of fuel and oil on farms

P_H = the index of the national average farm wage rate

P_M = the index of the national average price of all farm machinery

P_R = the index of the national average, aggregate price received by farmers for all commodities

Q_B = U.S. farmers' total expenditures for buildings, excluding operators' dwellings, and land improvements

Q_e = U.S. farmers' total expenditures for electricity for farm use

Q_{fo} = U.S. farmers' total expenditures for fuel and oil for farm use

Q_H = the number of persons in the national hired farm labor force

Q_M = U.S. farmers' total expenditures for all farm machinery

The exogenous variables used in the above and later models are listed here.

E = the ratio of U.S. farmers' total equity to their total outstanding debt for farming purposes

P_{IS} = the index of the national average price of metals and metal products

P_N = the index of the national average hourly wage rate of all nonfarm, industrial workers

S_B = the stock of farm buildings excluding operators' dwellings on January 1 of the current year.

S_M = the stock of farm machinery on farms on January 1 of the current year

T = the time variable where $T = 47.0$ for 1947

TA = the total crop acreage in the U.S.

V = the three-year simple average of variation between expected and actual national net farm income

Y_{AF} = the three-year simple average of national net farm income

The subscript t denotes the current year; t-1 denotes the past year. A more detailed description of these variables and data sources is in Appendix A.

The variables, models, and systems presented in this section are used to analyze the demand for machinery and building and land improvements. The results of the analysis are presented in the next section.

Empirical Estimates of the National Demand Functions for Farm Machinery and Building and Land Improvements

Estimates of the parameters of the models described in the previous section and other models are presented in this section. These results allow us to test hypotheses of directional effects on demand of changes in explanatory variables. They also estimate the quantitative reaction of demand to changes in prices and other variables. With these estimates the changes in demand for machinery and building and land improvements due to changes in explanatory variables can be estimated.

The estimation procedures used are outlined in Chapter III. Fuller's modified limited information maximum liklihood estimator (MLIML) is used with $\alpha = 1$. Estimates are made with the data in original and logrithmic values. Data are from 1946 to 1977 and 1945 for lagged observations.

The results of the analysis of machinery demand are presented first followed by the analysis of building and land improvements demand. The structural coefficients and the elasticities are presented and discussed simultaneously.

Machinery demand

All farm machinery is grouped together for this analysis. Trucks, tractors, and automobiles for farm use are included. Other farm machinery and equipment such as combines, harvestors, planting equipment, and others are counted except for minor types of equipment counted as operating expenses. Separate analysis of these individual categories would be useful and is being done in another study. Analysis of aggregate machinery purchases, while it does lose some detail, is a good measure of overall changes. Many machines are complements of each other so total purchases do capture the changes in factors affecting machinery demand.

Farmers' demand for machinery is hypothesized to be a function of its own price, the price of fuel and oil, the farm wage rate, all prices received by farmers, total U.S. crop acreage and average acreage per farm, the ratio of farmers' equity to their outstanding debt, national net farm income, the variation between expected and actual net farm income, the stock of machinery on farms, and other, slowly changing variables represented by a time variable. These variables are incorporated into several models of machinery demand. The empirical estimates of these models are presented in this section. From these estimates, hypotheses can be tested and the quantitative effects of changes in explanatory variable can be estimated.

Several formulations of the machinery demand models are used to achieve theoretically correct signs on the price ratios. Fuel and oil, although expected to have a negative coefficient as a complement to machinery is estimated to have a positive coefficient in model (4.25) (Table 4.2); in model (4.26) fuel and oil has the expected sign but the machinery price and the wage rate do not. These wrong signs and relatively high mean square errors create an interest in other formulations.

When the current and lagged ratios of machinery price to all

Table 4.2. Estimates of structural coefficients of demand for farm machinery[a]

Model	s^2	$\hat{R}^{2}$[b]	Intercept	$\frac{P_M}{P_{Rt}}$	$\frac{P_M}{P_{Rt-1}}$
4.25	429,707	.983	-36,747 (14,645)	-13,908 (7,034)	
4.26	568,279	.967	26,989 (17,351	12,040 (9,718)	
4.27	295,421	.976	-2,897 (3,189)		-4,134 (2,036)
4.28	477,569	.969	-6,979 (6,004)		
4.29	433,660	.965	-7,100 (5,906)		
4.30	290,560	.983	2,132 (3,425)		
4.31	110,583	.990	-12,998 (2,826)	-5,114 (1,079)	
4.32	201,280	.982	-66,654 (22,619)	-5,950 (2,368)	
4.33	335,839	.968	-74,572 (37,127)		
4.34[c]	.0223		-63 (90)		
4.35[c]	.0171		6 (9)	-.45 (.27)	

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or Appendix A for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

$\frac{P_M}{P_{Ht}}$	$\frac{P_M}{P_{Ht-1}}$	$\frac{P_H}{P_{Rt}}$	$\frac{P_{fo}}{P_{Rt}}$	A'_t	TA_t
		11,671	11,489		
		(9,344)	(5,803)		
		-18,095	-11,686		
		(12,224)	(7,750)		
-8,586	9,246				
(4,645)	(5,101)				
-8,359	9,120				
(4,584)	(4,781)				
-1,671					
(1,168)					
				20	.003
				(17)	(.001)
					.039
					(.013)
-5,540					.051
(3,611)					(.026)
-.11					
(.77)					
				-.68	
				(1.39)	

Table 4.2 continued

E_t	Y_{AFt-1}	V_{t-1}	S_{Mt}	T	Q_{Mt-1}	ρ
	.26	-.00008		421		-[d]
	(.09)	(.00003)		(116)		
				-124	.80	.18
				(129)	(.30)	(.35)
	.12	-.00005		145		.38
	(.08)	(.00002)		(51)		(.19)
	.28	-.00004	-.002	102		.27
	(.12)	(.00003)	(.085)	(55)		(.13)
	.28	-.00004		102		.39
	(.12)	(.00003)		(48)		(.21)
88				9	.63	.15
(114)				(33)	(.17)	(.22)
	.29	-.00005		73		.52
	(.07)	(.00001)		(117)		(.13)
	.33	-.00006		432		.45
	(.10)	(.00002)		(128)		(.17)
	.34	-.00004		333		.52
	(.14)	(.00003)		(142)		(.17)
4.6	.44	-.004		.031		.49
(6.2)	(.44)	(.042)		(.028)		(.15)
	-.17	-.027		.024	.86	-.38
	(.40)	(.035)		(.029)	(.25)	(.32)

[d]Autocorrelation is insignificant so the model is reestimated with no such coefficient.

prices received are specified, the coefficient of the current ratio has the wrong sign and is insignificant even though the model is over identified. Model (4.27) is estimated with only the lagged ratio; all signs are theoretically correct, the mean square error is lower than models (4.25) and (4.26), and, except for the intercept, all coefficient estimates are statistically significant. Similar problems are encountered when the current and lagged ratios of machinery price to the farm wage rate are specified in models (4.28) and (4.29). In both models we can have ninety percent confidence that the ratios' coefficient estimates are not equal to zero, but the lagged ratio has a positive, rather than the expected negative, coefficient estimate.

In those models with fairly stable coefficient estimates and acceptable signs, machinery demand is estimated to be elastic with respect to its own price (Table 4.3). The long-run elasticity estimates range from -0.8 in model (4.27) to -2.8 in model (4.25). Excluding model (4.25) since it includes the lagged price ratio and not the current ratio and model (4.27) because of the wrong coefficient sign on fuel and oil price, the long-run demand elasticity with respect to the machinery price ranges from -1.0 in model (4.31) to -1.4 in model (4.33). In model (4.30) the short-run elasticity is estimated to be -0.4 and the long-run elasticity is estimated to be -1.1. Hence, a ten percent rise

Table 4.3. Estimated elasticities of demand for farm machinery with respect to prices and other variables[a]

Model	$\frac{P_M}{P_{Rt}}$	$\frac{P_M}{P_{Rt-1}}$	$\frac{P_M}{P_{Ht}}$	$\frac{P_H}{P_{Rt}}$	$\frac{P_{fo}}{P_{Rt}}$	A'_t	TA_t	E_t	Y_{AFt-1}	V_{t-1}
4.25	-2.77			2.22	2.47				.98	-.14
	(1.40)			(1.78)	(1.25)				(.35)	(.05)
4.27		-.80							.45	-.08
		(.39)							(.32)	(.04)
4.30[b]			-.42					.16		
			(.29)					(.20)		
4.31	-1.02					1.41	0.9		1.11	-.08
	(.21)					(1.23)	(0.1)		(.26)	(.02)
4.32	-1.19						10.5		1.25	-.09
	(.47)						(3.7)		(.37)	(.04)
4.33			-1.39				13.9		1.28	-.06
			(.91)				(7.1)		(.54)	(.04)
4.35[c]	-.45					-.68			-.17	-.03
	(.27)					(1.39)			(.40)	(.04)

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Long-run estimates for the adjustment or expectation model can be estimated by using the coefficient on the lagged dependent variable.

[c]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

in the machinery price relative to all prices received is estimated to cause machinery demand to fall by ten to twelve percent or up to twenty-eight percent by model (4.25) if all other factors are stable. Machinery demand is slightly more elastic with respect to its price relative to the farm wage rate; a ten percent rise in this ratio is estimated to cause an eleven to fourteen percent decline in demand.

The elasticities of machinery demand with respect to prices received and the farm wage rate can be estimated by using the coefficient estimate of the appropriate price ratio. The elasticity with respect to prices received is estimated to range from 0.8 in model (4.27) using the lagged ratio to 1.2 in model (4.32). The long-run elasticity with respect to the farm wage rate is estimated to range from 1.1 in model (4.30) to 1.4 in model (4.33); the short-run elasticity is estimated to be 0.4 in model (4.30). From these estimates machinery demand can be expected to respond elastically with respect to both prices received by farmers and the farm wage rate.

For the most part, Heady and Tweeten (1963) and Minden (1965) do not estimate the price elasticities to be as high as these estimates. Heady and Tweeten estimate the elasticity to be about -0.75 using the data in original form and -1.5 using the data in logarithmic form; their data are annual figures from 1926 to 1959 excluding 1942 to 1947. Minden estimates the price elasticity of demand for all machinery to be -0.85 for the period 1911 to 1962.

The higher price elasticities estimated in this study reflect several things. The recent data period used covera time when farm machinery essentially has replaced all horse power. Machinery is now an integral part of the farm business and stocks have been built up. Thus, the greater response to prices can be from the national demands reflecting adjustments to prices and not just additions to the farm stock of machinery. As knowledge of the production function of an input increases, and producers find the marginal product higher than the marginal cost, the input will be added to the production process even though its relative price is increasing. So it has been with machinery in the past; now as the productivity of machinery is known with more certainty, producers adjust quicker to price changes. Also, the general level of education of farmers has increased over time thus increasing their management ability and responsiveness to market conditions.

In model (4.31) the average number of acres per farm is estimated to have a significant, positive effect upon the demand for machinery. The response is elastic. However, this is not the case in every model estimated. In model (4.35) and other, unreported models, the effect of the acreage per farm is unstable.

Machinery demand responds positively to changes in the total crop acreage. This is expected. Demand is estimated to be quite responsive to changes in total acreage. In model (4.31) a one percent increase in total acreage is estimated to cause a 0.9 percent increase in machinery demand; in models (4.32) and (4.33) the increase is estimated to be ten and one-half to fourteen percent, but these latter estimates are unreasonable.

In models (4.30) and (4.34) the ratio of farmers' equity to outstanding debt has an unstable effect. The effect is positive in both models but the standard error of the coefficient is greater than the coefficient in both models.

As hypothesized, net farm income and its variation are estimated to have positive and negative effects, respectively, upon the demand for machinery. The income elasticity of demand is estimated to range from 0.45 in model (4.27) to 1.3 in model (4.33). Variation between expected and actual net farm income has a decreasing effect but it is quite small.

These estimates fall inbetween the range of income elasticities estimated by Heady and Tweeten (1963) and Minden (1965). For the period 1926 to 1959 excluding 1942 to 1947, Heady and Tweeten have income elasticity estimates ranging from 0.4 to 0.8. Minden estimates the income elasticity to be 0.45 for the period 1911-1962 and 3.66 for the period 1946 to 1962. The increases in income elasticity over time is explained by the same reasons mentioned earlier for price elasticities: growth in stock level, greater knowledge of machinery productivity and better management ability.

The slowly changing variables have a positive and significant upon machinery demand. In model (4.26) the time coefficient is negative and unstable but model (4.26) is not considered because of the impact of lagged machinery purchases upon it.

The lagged value of machinery purchases, while its coefficient is significant, is thrown out of the model. The coefficients of the other variables are unacceptable in models (4.26) and (4.30). The stock of farm machinery does not have a significant effect upon machinery demand as exemplified by model (4.28); it is not considered a part of the true model. Also, the logarithmic formulation is rejected for use as a model of machinery demand; models (4.34) and (4.35) show the characteristically unstable coefficients found in this type of model.

From this analysis we can see that farmers' demand for machinery is a function of current price ratios, total and per farm acreages, total of and variations in national net farm income, and other, slowly changing variables. The stock of machinery and last years' expenditures do not have significant effects. The results of the analysis of demand for building and land improvements are reported next.

Building and land improvements demand

Building and land improvements include new construction, additions, and major improvements of service buildings, other structures, fences, windmills, wells, dams, ponds, terraces, drainage ditches, tile lines, and dwellings not occupied by farm operators. Farmers' demand for building and land improvements is hypothesized to be a function of the prices of building and fencing materials and fuel and oil, the farm wage rate, the per acre value of U.S. farmland, the prices received by farmers, the number and size of farms, the total crop acreage, the ratio of farmers' equity to outstanding debt, national net farm income, the variation between expected and actual net farm income, the stock of farm buildings, and other, slowly changing variables represented by a time variable. The variables are formulated into several models to test hypotheses and to estimate the quantitative effects of these variables upon farmers' demand for improvements.

The demand for building and land improvements behaves as expected in response to its own price and the prices of complements and substitutes (Table 4.4). In all models demand response is quite elastic with respect to its own price (Table 4.5). The short-run price elasticity estimates range from -2.7 in model (4.42) to -3.7 in model (4.39). Models (4.37) through (4.40) have the lowest mean square error of the models using the data in

Table 4.4. Estimates of structural coefficients of demand for building and land improvements[a]

Model	s^2	$\hat{R}^{2\,b}$	Intercept	$\frac{P_B}{P_{Rt}}$	$\frac{P_H}{P_{Rt}}$
4.36	4,458	.998	-1,913 (277)	-4,832 (499)	-434 (188)
4.37	3,934	1.000	787 (1,146)	-4,694 (456)	
4.38	3,941	1.000	2,253 (882)	-4,742 (475)	
4.39	4,275	1.000	-1,177 (3,210)	-5,382 (1,064)	
4.40	3,687	1.000	1,666 (269)	-4,492 (414)	
4.41	4,621	.999	1,309 (2,127)	-3,465 (629)	
4.42	4,659	.999	611 (943)	-3,832 (785)	
4.43	7,341	.997	4,440 (1,595)	-2,240 (292)	
4.44	4,739	.999	-1,564 (698)	-4,779 (549)	
4.45[c]	.00457		20.67 (7.32)	-3.38 (.53)	-.74 (.26)
4.46[c]	.00283		4.72 (3.11)	-2.75 (.31)	
4.47[c]	.00634		2.61 (1.92)	-3.12 (.67)	

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or Appendix A for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

$\frac{P_{fo}}{P_{Rt}}$	$\frac{P_{FL}}{P_{Rt}}$	A'_t	TA_t	N_t	E_t	Y_{AFt-1}
2,453	2,159					
(439)	(188)					
2,518	1,628				23	
(432)	(240)				(30)	
2,337	1,912					-.009
(389)	(265)					(.012)
2,640	2,410		.002			
(557)	(451)		(.003)			
2,259	1,763					
(363)	(158)					
1,499	1,473			-.07		.016
(674)	(251)			(.18)		(.017)
1,769	1,474	-.53				.009
(651)	(239)	(3.80)				(.015)
1,792				-.20	-9	
(293)				(.15)	(33)	
2,829	1,179	-3.5			59	
(467)	(217)	(2.2)			(26)	
1.14	2.31					
(.58)	(.77)					
1.50	.57	-.41			.23	
(.35)	(.24)	(.50)			(.18)	
1.87	.31				.15	.15
(.80)	(.49)				(.25)	(.17)

Table 4.4 continued

Model	V_{t-1}	S_{Bt}	T	Q_{Bt-1}	ρ
4.36		-.03	23		-.28
		(.01)	(5)		(.19)
4.37	.000003	-.02	29		-.49
	(.000001)	(.01)	(13)		(.20)
4.38	.000005	-.03	14		-.45
	(.000003)	(.01)	(9)		(.20)
4.39	.000003	-.04	31		-.44
	(.000001)	(.02)	(14)		(.20)
4.40	.000003	-.02	19		-.44
	(.000001)	(.01)	(4)		(.19)
4.41	.000002		13		-.30
	(.000003)		(25)		(.21)
4.42	.000002		25		-.28
	(.000003)		(32)		(.21)
4.43	.000006		-27	.04	.00
	(.000002)		(19)	(.13)	(.26)
4.44			71	.11	-.36
			(15)	(.09)	(.22)
4.45^c		-1.24	-.004		-.15
		(.58)	(.023)		(.17)
4.46^c			.04	.31	-.39
			(.01)	(.07)	(.14)
4.47^c	.006		.04		-.18
	(.021)		(.02)		(.17)

Table 4.5. Estimated elasticities of demand for building and land improvements with respect to prices and other variables, selected models[a]

Calculated from model:	$\frac{P_B}{P_{Rt}}$	$\frac{P_H}{P_{Rt}}$	$\frac{P_{fo}}{P_{Rt}}$	$\frac{P_{FL}}{P_{Rt}}$	A'_t	TA_t	E_t	Y_{AFt-1}	V_{t-1}
4.36	-3.35	-.26	1.65	1.26					
	(.35)	(.11)	(.30)	(.11)					
4.37	-3.26		1.70	.95			.13		.015
	(.32)		(.29)	(.14)			(.16)		(.007)
4.38	-3.29		1.58	1.11				-.11	.026
	(.33)		(.26)	(.15)				(.15)	(.013)
4.39	-3.73		1.78	1.40		.002			.015
	(.74)		(.38)	(.26)		(.002)			(.007)
4.40	-3.12		1.52	1.02					.018
	(.29)		(.24)	(.09)					(.006)
4.42	-2.66		1.19	.86	-.12			-.11	.012
	(.54)		(.44)	(.14)	(.86)			(.18)	(.017)
4.44[b]	-3.32		1.91	.69	-.78		.33		
	(.38)		(.31)	(.13)	(.49)		(.14)		
4.45[c]	-3.38	-.74	1.14	2.31					
	(.53)	(.26)	(.58)	(.77)					
4.46[b,c]	-2.75		1.50	.57	.41		.23		
	(.31)		(.35)	(.24)	(.50)		(.18)		

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Long-run estimates for the adjustment or expectation model can be estimated by using the coefficient on the lagged dependent variable.

[c]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

original form. In these four models the price elasticity estimates range from -3.1 in model (4.40) to -3.7 in model (4.39). Using model (4.44) as an adjustment model the short-run price elasticity is estimated to be -3.3 and the long-run elasticity to be -3.7. Hence, a ten percent rise in the price of building and fencing materials with all other factors constant is estimated to cause a thirty-one to thirty-seven percent decline in the demand for improvements.

The farm wage rate has a significant effect on the demand for improvements only in models formulated as in models (4.36) and (4.45). In both of these models, labor is estimated to be a complement to building and land improvements, but the response is inelastic. In model (4.36) the cross-price elasticity of demand is estimated to be -.26, and it is estimated to be -.74 in model (4.45).

The cross-price elasticity of demand with respect to fuel and oil is estimated to range from 1.1 in model (4.45) to 1.8 in model (4.39). The short-run elasticity is estimated to be 1.9 and the long-run elasticity, 2.1 in model (4.44). A ten percent rise in the price of fuel and oil is estimated to cause a rise in improvements demand of eleven to twenty-one percent with all other factors constant which is an elastic response.

Farmers' demand for building and land improvements is estimated to have an almost unitary response to the per acre value of farmland as a substitute for improvements. The cross-price elasticity of demand is estimated to range from 0.9 in model (4.42) to 1.4 in model (4.39). The adjustment models of (4.44) and (4.46) estimate the short-run elasticity to be 0.7 and 0.6, respectively, and the long-run elasticity to be 0.8 in both models. A ten percent rise in the per acre value of farmland is estimated to cause an eight to fourteen percent increase in demand for improvements in the long-run.

The average number of acres per farm does not have a consistently significant effect upon demand for improvements. In model (4.44) demand is estimated to respond negatively and inelastically to changes in farm size. This effect was found in the analysis by Hoffmann and Heady (1962), also. In model (4.39), the total U.S. crop acreage is estimated to have no significant effects on demand for building and land improvements. In model (4.41) the number of farms has an insignificant coefficient; in model (4.43) the coefficient is significant but the model is not considered due to instability of other coefficients.

Only in model (4.44) does the equity ratio have a significant effect upon demand. In other formulations the ratio does not have a significant coefficient. Demand response is quite inelastic to equity ratio changes.

National net farm income also has no significant effect upon demand for building and land improvements. The variation in income does have a significant, positive effect on demand. However, the response in demand is quite inelastic to changes in income variation.

Model K in Chapter II could be used to interpret the effect of including the stock of farm buildings. However, Model K does not fit the results. In Model K the values of the depreciation rate and the adjustment coefficient cannot be determined without outside information. An estimate of the adjustment rate could come from an adjustment model such as model (4.44); an estimate of the depreciation rate could come from historical records or by assumption.

The coefficient estimate for the stock of buildings ranges from -.02 to -.04 excluding model (4.45). The adjustment coefficient, g, estimated in model (4.44) is 0.89; using this adjustment coefficient, the estimate of the depreciation rate is estimated to range from 0.85 to 0.87 which seems quite high. An estimate of the depreciation rate can be calculated by assuming straight-line methods and an average life span of improvements. If an average life of twenty-five years is assumed, the depreciation rate is estimated to be 0.04; thus, adjustment coefficient is estimated to range from 0.06 to 0.08 depending upon the model considered which seems quite low. So model K is considered to be inappropriate to analyze farmers' demand for improvements.

A simpler model may be more appropriate to analyze demand. Since the coefficient on the stock of buildings is consistently negative, it does not seem realistic to call this an estimate of the depreciation rate. What the negative coefficient says is: the larger the stock of buildings, the less the demand for improvements. This seems realistic but perhaps too simple for model-builders. Model (4.45) which is estimated using logarithmic data supports this simpler formulation.

The other, slowly changing variables have a positive effect on improvements demand. In those models not excluded due to unstable coefficients the coefficient on time is estimated to be positive and significant.

When the data are used in original form, the lagged value of expenditures on improvements is rejected as part of the true model. The mean square error is lower in models not containing the lagged variable. In model (4.44) the lagged expenditures has an estimated coefficient of which we can have eighty-five percent confidence that the true parameter is different from zero. The estimates of the other models are near the estimates of model (4.44) so little information is lost by excluding the lagged variable.

In this analysis we have tested the hypotheses of what variables have significant impacts upon farmers' demand for building and land improvements. The quantitative effects of these relationships are estimated. The demand for improvements is seen as a function of current prices of building and fencing materials and all prices received by farmers, the variation in net farm income, the stock of farm buildings, and other, slowly changing variables.

Summary

Farmers' demands for machinery and building and land improvements are analyzed separately in this chapter. The qualitative and quantitative effects upon machinery and improvements demand are estimated in econometric models.

Expenditures for machinery and improvements have increased in real terms since 1945. However, the purchases have been made up of heterogeneous parts over time. For this study the total expenditure level is analyzed versus the components of the total. The changes in total machinery demand and in total improvements demand are hypothesized to be caused by various variables that farmers consider in their decision analysis.

The demand for machinery is hypothesized to be a function of the machinery price, the fuel and oil price, the farm wage rate, and all prices received by farmers. The demand for building and land improvements is hypothesized to be a function of the price of building and fencing materials, the fuel and oil price, the per acre value of U.S. farmland, the farm wage rate, and all prices received by farmers. These prices are included as ratios in the analysis.

Other variables affect machinery and improvements demand. Net farm income and the variation between expected and actual net farm income indicate potential returns and risks of investments. Farmers' equity ratio, the number and size of farms, total crop acreage, and farm stocks of machinery and buildings are hypothesized to influence the demand for machinery and improvements.

These variables are formulated into several demand models for machinery and building and land improvements. These models are specified as part of a system of models of other resource markets. Fuller's modified limited information maximum likelihood estimator with $\alpha = 1$ is used to estimate the parameters of the models. Estimates are made with the data in original and logarithmic values. Data are from 1946 to 1977 and 1945 for lagged observations.

Several formulations of the machinery demand models are used to achieve theoretically correct signs on the price ratios. In those models with fairly stable coefficient estimates and acceptable signs, machinery demand is estimated to be elastic with respect to the current machinery price. A ten percent rise in the machinery price relative to all prices received is estimated to cause machinery demand to fall by ten to twelve percent or up to twenty-eight percent by model (4.25) if all other factors are constant. Machinery demand is slightly more elastic with respect to its price relative to the farm wage rate than to its price relative to all prices received. Machinery demand is estimated to be elastic in response to all prices received and the farm wage rate.

As the acreage per farm and total acreage change, machinery demand is estimated to respond in the same direction. The demand for machinery is estimated to be quite responsive to changes in total crop acreage.

National net farm income and the variation between expected and actual net farm income are estimated to have significant positive and negative effects, respectively, on machinery demand. The income elasticity of demand is estimated to be greater than 1.0.

Other, slowly changing variables have a positive impact on machinery demand over time. The stock of machinery and last year's expenditures do not have significant, estimated effects.

Farmers' demand for building and land improvements behaves as expected in response to its own price and the prices of complements and substitutes. Demand is quite elastic with respect to its own price and the price of fuel and oil which is estimated to be a substitute of building and land improvements. Demand responds inelastically to the farm wage rate as a complement. The effect of the value of farmland is significant and its cross-price elasticity is expected to be near unity.

The number and size of farms do not have consistently significant effects upon demand for improvements. Total crop acreage also has no significant effect. The equity ratio does not have a consistent significant effect either. Neither do national net farm income or the variation in net farm income.

The stock of buildings does have a significant but negative effect upon the demand for improvements. This does not fit any of the models discussed in Chapter II and is considered to be the simple impact of the stock level upon demand.

Other slowly changing variables do have a significant positive effect on improvements demand. When the data are used in original form, the lagged value of expenditures on improvements is rejected as part of the true model due to insignificance and improved mean square error in other models.

In this chapter the results of the analysis of farmers' demand for machinery and for building and land improvements are discussed. In the next chapter farmers' demand for farm labor is analyzed.

CHAPTER V. DEMAND FOR FARM LABOR

The intrinsic, human element of farm labor makes the historical downward trend in farm employment a highly emotional issue. It is a subject more politically volatile than land and capital, the other two components of the traditional trio of resources. Changes in the level of machinery purchases and fertilizer usage do not create the concern that changes in farm employment and population do. The concern is shared by people in and out of farming.

The issue of farm labor involves the economic well-being of farmers and farm workers and, as some proponents of family farming say, the very fiber of democratic society. The pioneer heritage of farming, the love of the land and the way-of-life, and the historical independence of Americans have combined to make the discussions about farm labor and returns to farm labor more than just a rational economic discussion. The solutions of low returns to farm labor and slowing or reversing the decline in the number of farmers involve these ideas and beliefs just mentioned as well as economics.

Thomas Jefferson, the third president of the U.S., argued that farming was not only the source of economic worth but was also the source of moral virtue in a democratic society (Gulley, 1974, p. 25). To be a source of moral virtue, Jefferson felt that a nation needed to consist mainly of small, independent family farmers. Even though these conditions have disappeared in the U.S., the Jeffersonian concept is used to extol the virtues of the smaller, independent farmer.

U.S. farm population has decreased both in absolute terms and relative to the total population (Table 5.1). Farm population as a percentage of the total population has fallen from 35% in 1910 to 3.5% in 1977. Farm employment has also fallen (Table 5.2 and Figure 5.1). The number of family workers has decreased at a faster rate than hired workers on U.S. farms. The estimate of 1977 total farm employment is less than a third of 1910 total employment. National net farm income measured in 1967 dollars has increased 20 percent from 1920 to 1977 (Table 5.3). Average net farm income per farm in 1967 dollars has almost doubled from 1910 to 1977 reflecting a halving in the number of farms. These figures represent national levels and do not indicate anything about regional changes. Nor do these figures show why the changes have occurred.

Prices, as well as income, are expected to influence farm labor demand. Relative to all prices received by farmers, the farm wage rate and the prices of machinery and fuel and oil have risen since 1945 (Figure 5.2). These two inputs are ex-

Table 5.1. U.S. population: total and farm, selected years, 1910-1977[a]

Year	Total population	Farm population Number	Farm population Percentage of total
	(000)	(000)	(%)
1910	91,885	32,077	34.9
1920	106,089	31,974	30.1
1930	122,775	30,529	24.9
1940	131,820	30,547	23.2
1945	139,583	24,420	17.5
1950	151,132	23,048	15.3
1955	164,607	19,078	11.6
1960	180,007	15,635	8.7
1965	193,709	12,363	6.4
1970	204,335	9,712	4.8
1975	213,056	8,864	4.2
1977	216,399	7,806	3.6

[a]Sources: U.S. Department of Agriculture, 1962, 1972, 1978).

Table 5.2. U.S. Farm Employment, Selected Years, 1910-1977[a]

Year	Total employment: Average number of persons	Total employment: Index 1967=100	Family workers: Average number of persons	Family workers: Index 1967=100	Hired workers: Average number of persons	Hired workers: Index 1967=100
	(000)		(000)		(000)	
1910	13,555	276	10,174	279	3,381	270
1920	13,432	274	10,041	275	3,391	271
1930	12,497	256	9,307	256	3,190	247
1940	10,979	225	8,300	228	2,679	208
1945	10,000	206	7,881	217	2,119	163
1950	9,926	203	7,597	208	2,329	182
1955	8,381	172	6,345	172	2,036	158
1960	7,057	144	5,172	142	1,885	145
1965	5,610	114	4,128	113	1,482	118
1970	4,523	92	3,348	92	1,175	94
1975	4,342	89	3,026	83	1,317	105
1977	4,152	85	2,856	78	1,296	103

[a]Sources: (U.S. Department of Agriculture, 1962, 1972, 1978).

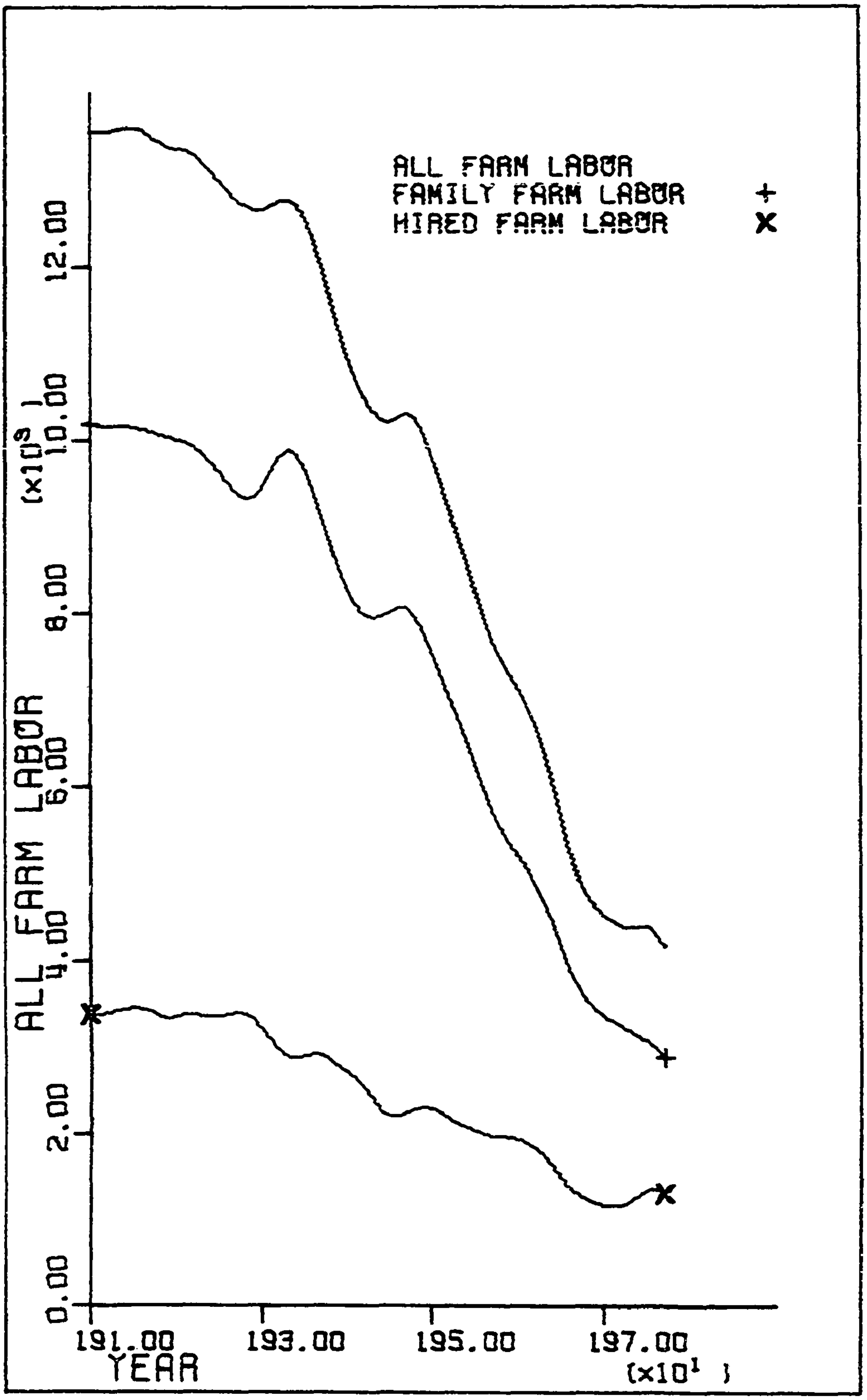

Figure 5.1. The total farm labor force and its family and hired farm labor components.

Table 5.3. Number of farms and total and per farm net income in current and 1967 dollars, selected years 1910-1977[a]

Year	Number of farms	Total net income[b] current dollars	Total net income[b] 1967 dollars	Per farm income[b] current dollars	Per farm income[b] 1967 dollars
	(000)	-(million dollars) -		- - -(dollars) - - -	
1910-14 ave.	6,429	3,984	13,759	620	2,141
1920-24 ave.	6,500	5,086	9,466	782	1,456
1930-34 ave.	6,672	3,023	6,939	454	1,041
1940	6,350	4,482	10,671	706	1,681
1945	5,967	12,312	22,842	2,063	3,827
1950	5,648	13,648	18,929	2,417	3,352
1955	4,654	11,305	14,096	2,429	3,029
1960	3,963	11,518	12,985	2,907	3,277
1965	3,356	12,899	13,650	3,843	4,067
1970	2,949	14,151	12,168	4,799	4,126
1975	2,767	24,475	15,183	8,845	5,487
1977	2,706	20,543	11,318	7,592	4,183

[a]Source: (U.S. Department of Agriculture, Economics, Statistics, and Cooperative Service, 1978, p. 32-34).

[b]Net farm income including government payments and after inventory adjustment.

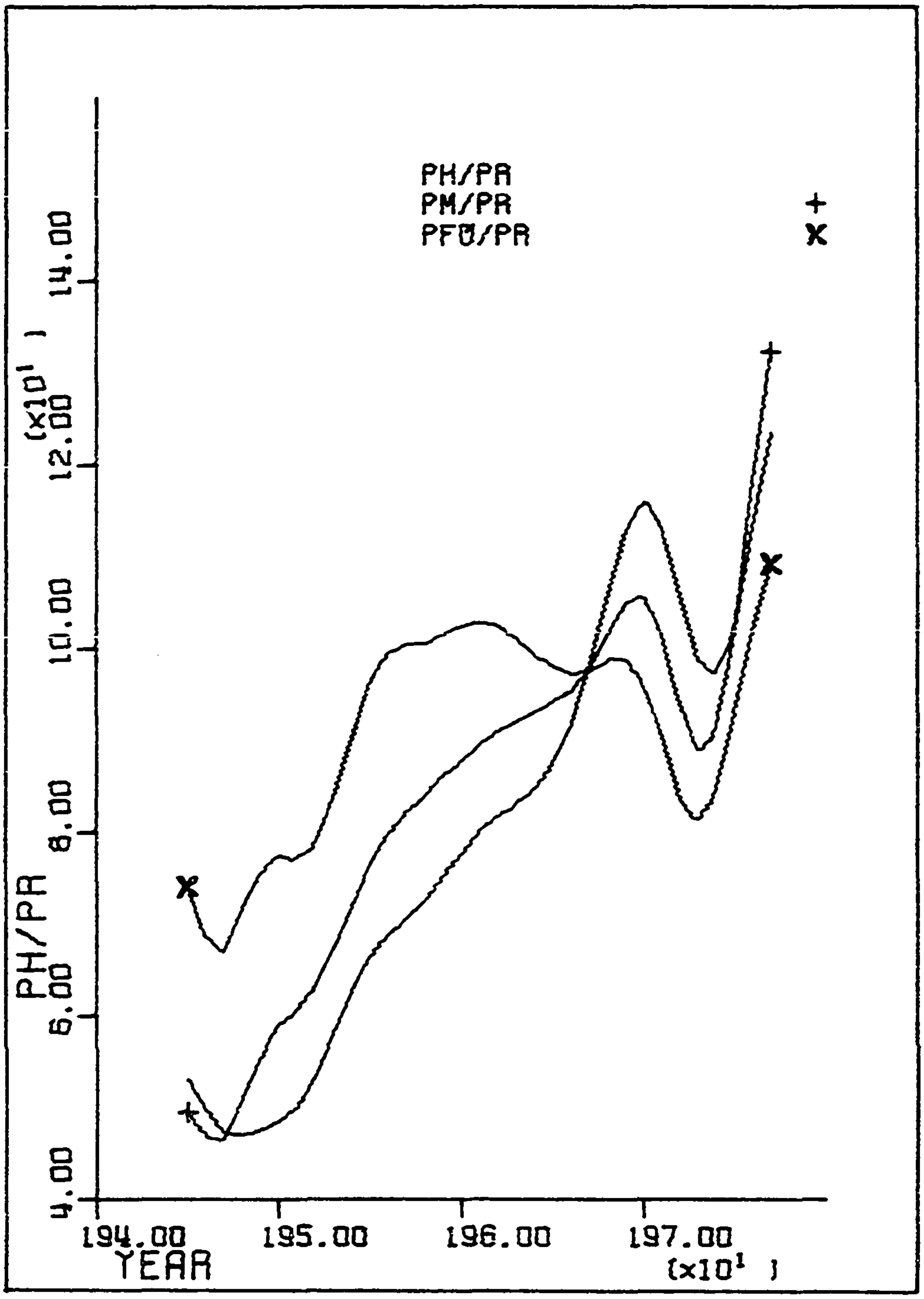

Figure 5.2. Indices of the farm wage rate, the machinery price, and the price of fuel and oil relative to all prices received by farmers, P_H/P_R, P_M/P_R, and P_{fo}/P_R, 1945-1977.

pected to be substitutes for farm labor. The price of machinery has increased more than the farm wage rate and the price of fuel and oil relative to all prices received.

For a better understanding of farm employment and the explanatory forces behind employment changes, the effects of income, prices, and other factors need to be estimated. By knowing these effects, we can estimate the effects of future changes.

In this chapter, variation in farm employment is explained by several factors. Hired and family labor are used as explanatory factors of each other in some models. Wage rates, relative to prices received by farmers, are included in hired labor models. The relationships between nonfarm and farm wage rates and national unemployment rates are used to explain family labor demand.

The models used for labor demand are explained briefly in the next section. Then the estimates of the parameters of the models are presented. A short summary is at the end of the chapter.

Models of Labor Demand

The two components of farm labor, hired and family workers, are treated separately in this analysis. Models of hired farm labor demand are similar to demand models for other resources. For family labor different models are needed to account for different methods of allocation for that resource.

The demand for farm labor is considered to be a function of farm wage rates and prices of complements and substitutes, all relative to prices received; net farm income; farmers' equity to debt ratio; the stock of machinery; the nonfarm to farm hourly wage ratio; the national unemployment rate; the variance between actual and expected net farm income; the number of farms, the average farm size; the level of the other labor component; and other, slowly changing variables accounted for with a time variable. The reasons for including these variables in the analysis are summarized here and in Chapter II.

Resource demand will respond inversely to its own and complements' price changes and directly to substitutes' price changes. Most major resources in agriculture are substitutes for labor, and labor; demand is assumed to move directly with the price changes of those resources. Prices received for farm products are assumed to have direct effects upon labor demand. The amount of response from a given price change depends upon the interrelationships between all resources. It is these degrees of response, these interrelationships, that this analysis is measuring.

High net farm income indicates better return to resources which increases the demand for labor. The equity ratio measures financial soundness and the farmers' ability to weather bad years and stay in farming. The variance between actual and expected net farm income is a measure of the risk and uncertainty that a farmer faces in prices, productivity, and other forces.

The nonfarm to farm hourly wage ratio indicates the relative earning power of labor. As this ratio increases the pull from farm to nonfarm employment grows. The national unemployment rate indicates whether the move from farm to nonfarm employment is possible. Unemployment may be high enough that no jobs are open even though the wage ratio points towards moving to nonfarm jobs.

Machinery is a substitute for labor and the stock of machinery indicates the level of substitution. The number of farms and average farm size are indicators of labor changes as machinery and other resources replace labor.

Although they respond to different sets of variables, hired and family labor also respond to changes in each other. Other, more slowly changing variables affect labor demand as well; the effect of these are accounted for by including a time variable in the demand models.

These variables are used to delineate several labor demand models and are not used together in one model necessarily. From the general models discussed in Chapter II, a few models are presented here as applicable to farm labor. Hired farm labor demand fits an adjustment model easily since farmers will adjust their demand for labor in relation to the other resources and prices but the adjustment is not instantaneous. Factors that will affect hired labor demand are the wage rate relative to the prices received, P_H/P_R; the price for fuel and oil relative to the prices received, P_{fo}/P_R; the family labor force, Q_F; and the stock of machinery, S_M. Combining these and a time variable, a model similar to (2.16) is obtained:

$$Q^*_{Ht} = a + b(P_H/P_R)_t + c(P_{fo}/P_R)_t + dQ_{Ft} + eS_{Mt} + fT + u_t \quad (5.1)$$

where Q^*_{Ht} is the desired or optimal level of demand for hired farm labor. Model (5.1) may be used as it is by substituting the actual levels of the hired labor force for the desired levels.

Actual adjustment in hired farm labor in the current year is assumed to be a constant proportion of the difference between the desired level in the current year and the actual hirings during the past year:

$$Q_{Ht} - Q_{Ht-1} = g(Q^*_{Ht} - Q_{Ht-1}) \quad (5.2)$$

To develop an adjustment model similar to Model J in Chapter II, (5.1) is substituted into (5.2) and solved for Q_{Ht}:

$$Q_{Ht} = ag + bg(P_H/P_R)_t + cg(P_{fo}/P_R)_t +$$
$$dgQ_{Ft} + egS_{Mt} + fgT +$$
$$(1-g)Q_{Ht-1} + gu_t \quad (5.3)$$

Once (5.3) has been estimated, the long-run coefficients of (5.1) can be calculated using the adjustment coefficient, g, estimated from the coefficient on Q_{Ht-1}. Long-run and short-run elasticities are estimable.

Alternative specifications of (5.1) include substituting net farm income, Y_F, for Q_F:

$$Q^*_{Ht} = a + b(P_H/P_R)_t + c(P_{fo}/P_R)_t +$$
$$dY_{Ft-1} + eS_{Mt} + fT + u_t \quad (5.4)$$

or substituting the equity ratio for Q_F:

$$Q^*_{Ht} = a + b(P_H/P_R)_t + c(P_{fo}/P_R)_t +$$
$$dE_t + eS_{Mt} + fT + u_t \quad (5.5)$$

Adjustment models analogous to (5.3) for these desired-level models can be derived readily. Other variables may be used to form additional models of hired farm labor. Different combinations of variables can be used to formulate other desired-level models such as in (5.1). In each case, adjustment models can be formulated and the long-term, as well as the short-term coefficients can be estimated.

The level of family farm employment is specified differently from other agricultural inputs. It is different because a family worker decides for himself/herself between farm and nonfarm employment. There is demand for working on the farm from the potential income flow and there is demand for nonfarm employment due to potential earnings. But family workers may not move between farm and nonfarm employment with complete freedom. A high unemployment rate will discourage any movement of labor even though farm income may be relatively low.

In another sense this is also the supply of family labor in agriculture. A family worker may stay in agriculture even though returns are greater elsewhere due to the nonmonetary benefits of farming. A family worker also bases his/her decision on the net income from farming, not on the actual levels of farm prices, and the net income from farming relative to income from nonfarm employment.

To include these variables, the initial family labor model is specified as:

$$Q_{Ft} = a + bY_{Rt-1} + cU_{t-1} + dX \tag{5.6}$$

where Q_F is the level of family employment, Y_R is the ratio of nonfarm hourly wages to farm hourly wages, U is the national unemployment rate, and X stands for other explanatory variables. The coefficient on Y_R, b, is expected to be negative since increases in nonfarm wages relative to farm wages will draw labor away from agriculture.

The interaction between the wage ratio, Y_R, and the unemployment rate, U, may be a significant factor in family labor decisions. To explicitly include this interaction, Heady and Tweeten (1963) add an interaction term to (5.6):

$$Q_{Ft} = a + bY_{Rt-1} + dX + e\left(Y_R(1-U)\right)_{t-1} \tag{5.7}$$

It is doubtful that the unemployment rate by itself has any significant effect upon family farm employment so it is dropped from (5.7).

At some points in time, the unemployment rate may be high enough to preclude any movement from farm to nonfarm occupations even if farming has a low relative income. To account for this level of unemployment, this critical value, say V, model (5.7) is rewritten as:

$$Q_{Ft} = a + b\left(Y_R(1-U/V)\right)_{t-1} + dX \tag{5.8}$$

When U equals V the term in brackets in (5.8) becomes zero removing any impact Y_R has on Q_F; this is the effect just discussed. Assuming that b is negative the situation where U is greater than V the effect of Y_R becomes positive; this effect was observed during the depression as the number of agricultural workers increased.

Since U is estimated now and known to a certain degree of accuracy while V is not known, model (5.8) may be reformulated as:

$$Q_{Ft} = a + bY_{Rt-1} + \frac{-b}{V}(UY_R)_{t-1} + dX \tag{5.9}$$

The maximum effect of Y_R upon Q_F is b attained when the unemployment rate is zero. The value of V is calculated easily from the estimated coefficient of UY_R.

The variables denoted by X in (5.9) are those discussed with the models for hired farm labor demand except that X includes no price variables. Model (5.9) is used to estimate family farm employment in this analysis.

These models for hired and family farm labor demand are not assumed to be independent of other resource markets. Thus each model is estimated within a system of markets. The system is adjusted as needed for each model. The basic system for hired and family labor is described below.

$$Q_{Ht} = f\left((P_H/P_R)_t,\ (P_{fo}/P_R)_t,\ Q_{Ft},\ S_{Mt},\ T\right) \tag{5.10}$$

$$Q_{Ft} = f\left(Y_{Rt-1},\ (UY_R)_{t-1},\ Q_{Ht},\ T,\ Q_{Ft-1}\right) \tag{5.11}$$

$$(P_H/P_R)_t = f(Q_{Ht}, T, (P_H/P_R)_{t-1}) \tag{5.12}$$

$$(P_{fo}/P_R)_t = f(Q_{fot-1}, (P_e/P_R)_t, T) \tag{5.13}$$

$$Q_{fot} = f((P_{fo}/P_R)_t, (P_M/P_R)_t, (P_H/P_R)_t,$$

$$A'_t, Y_{AFt-1}, T, Q_{fot-1}) \tag{5.14}$$

$$(P_e/P_R)_t = f(Q_{et-1}, T) \tag{5.15}$$

$$Q_{et} = f((P_e/P_R)_t, A'_t, Y_{AFt-1}, V_{t-1}, T) \tag{5.16}$$

$$(P_M/P_R)_t = f((P_H/P_R)_t, (P_H/P_R)_{t-1}, (P_{fo}/P_R)_t,$$

$$P_{Nt}, T, (P_M/P_R)_{t-1}) \tag{5.17}$$

$$A'_t = f((P_{FL}/P_R)_{t-1}, (P_H/P_R)_{t-1}, T) \tag{5.18}$$

$$(P_{FL}/P_R)_t = f((P_M/P_R)_t, (P_H/P_R)_t, E_t, T) \tag{5.19}$$

The system's endogenous variables are:

Q_H = the number of persons in the national hired farm labor force,

Q_F = the number of persons in the national family farm labor force,

P_H = the index of the national average farm wage rate,

P_{fo} = the index of the national average price of fuel and oil on farms,

P_e = the index of the national average price of electricity on farms,

P_M = the index of the national average price of all farm machinery,

P_{FL} = the index of the average value of all U.S. farmland,

P_R = the index of the national average, aggregate price received by farmers for all commodities,

Q_{fo} = U.S. farmers' total expenditures for fuel and oil for farm use,

Q_e = U.S. farmers' total expenditures for electricity for farm use,

A' = the national average number of acres per farm in the U.S. on January 1 of the current year.

The system's exogenous variables are:

E = the ratio of U.S. farmers' total equity to their total outstanding debt for farming purposes,

S_M = the stock of farm machinery on farms on January 1 of the current year,

Y_{AF} = the three-year simple average of national net farm income,

V = the three-year simple average of variance between expected and actual national net farm income,

P_N = the index of the national average hourly wage rate of all nonfarm, industrial workers,

Y_R = the index of the ratio of nonfarm to farm national average hourly wage rates,

U = the national average unemployment rate, $0 \leq U \leq 1$,

UY_R = the product of U and Y_R, and

T = the time variable where T = 47.0 for 1947.

The subscript t denotes the current year; t-1 denotes the year just passed. Two variables not in the basic system but used in alternative systems and models are:

Q_M = U.S. farmers' total expenditures for all farm machinery and equipment for farm use expressed in 1967 dollars and

N = the number of farms in the U.S. on January 1 of the current year.

A more detailed description of these variables and the sources of data is in Appendix A.

The variables, models, and systems presented in this section are used to analyze the demand for hired and family farm labor. The results of the analysis are presented in the next section.

Empirical Estimates of the National Demand Functions for Farm Labor

Estimates of the parameters of the models just described are presented in this section. These results allow us to test hypotheses of directional effects on labor demand of changes in various variables. They also estimate the quantitative reaction of labor demand to changes in prices and other explanatory variables. With these estimates the changes in farm labor demand due to future trends and changes in U.S. agriculture can be estimated.

The estimation procedures used are outlined in Chapter III. Fuller's modified limited information maximum likelihood estimator (MLIML) is used with $\alpha = 1$. For some models of family farm labor demand which include as explanatory variables only predetermined variables, the ordinary least squares (OLS) procedure is used. Estimates are made with the data in original values and logarithmetic transformations also. Data are from the years 1946 to 1977 and 1945 for lagged observations.

Demand for hired farm labor is analyzed first and then family farm employment. The structural coefficients and the elasticities are presented and discussed together.

Hired farm labor demand

Hired farm labor is the nonfamily component of farm labor. It is hypothesized to be a function of the farm wage rate, the price of fuel and oil, the price of farm machinery, the prices received for farm goods, the number of family workers, the number of farms, the average farm size, the national net farm income, the variation in income, expenditures for and stock of farm machinery, and slow-changing variables grouped together in the time variable. These hypotheses are tested by estimating models of hired farm labor demand within a system of models of farm resource demand.

Models (5.20) through (5.30) support the hypothesis that demand for hired farm labor responds in the opposite direction to changes in the farm wage rate (Table 5.4). The results also show that hired farm labor changes in the same qualitative direction as changes in prices for machinery and fuel and oil

Table 5.4. Estimates of structural coefficients of demand for hired farm labor[a]

Model	s^2	$\hat{R}^{2b}$	Intercept	$\frac{P_H}{P_{Rt}}$	$\frac{P_{fo}}{P_{Rt}}$
5.20	6,141	.996	3,143	-2,273	
			(689)	(558)	
5.21	7,632	.997	-1,475	-1,667	487
			(1,953)	(593)	(585)
5.22	5,618	.998	-1,819	-1,735	774
			(1,601)	(578)	(368)
5.23	1,823	.999	-1,818	-1,078	881
			(1,034)	(430)	(550)
5.24	8,401	.996	-287	-1,908	700
			(2,689)	(477)	(354)
5.25	6,400	.997	2,084	-1,306	305
			(497)	(639)	(351)
5.26	2,911	.999	-5,043	-1,896	651
			(1,436)	(401)	(261)
5.27	8,143	.998	-4,826	-571	1,633
			(2,032)	(497)	(436)
5.28[c]	.0012	1.000	-8.7	-.54	.21
			(5.2)	(.20)	(.21)
5.29[c]	.0016	1.000	-5.1	-.47	.07
			(5.5)	(.30)	(.31)
5.30[c]	.0056	1.000	3.5	-1.47	.48
			(6.3)	(.59)	(.34)

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or Appendix A for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

$\frac{P_M}{P_{Rt}}$	Q_{Ft}	N_t	A'_t	Y_{AFt-1}	V_{t-1}	S_{Mt}
1,375				.006	.000002	
(341)				(.015)	(.000004)	
	.26					.01
	(.12)					(.01)
	.27					
	(.10)					
	.27					
	(.11)					
		.26				
		(.15)				
			-8.8			
			(4.2)			
	.46					
	(.08)					
	.48					
	(.13)					
	1.54					
	(.50)					
	.87					
	(.60)					
			.61			
			(1.20)			

Table 5.4. Continued

Model	Q_{Mt}	T	Q_{Ht-1}	ρ
5.20	[illegible]	[illegible]	[illegible]	[illegible]
5.21	[illegible]	[illegible]	[illegible]	[illegible]
5.22	[illegible]	[illegible]	[illegible]	[illegible]
5.23	[illegible]	[illegible]	[illegible]	[illegible]
5.24	[illegible]	[illegible]	[illegible]	[illegible]
5.25	[illegible]	[illegible]	[illegible]	[illegible]
5.26	[illegible]	[illegible]	[illegible]	[illegible]
5.27	[illegible]	[illegible]	[illegible]	[illegible]
5.28[d]	[illegible]	[illegible]	[illegible]	[illegible]
5.29[d]	[illegible]	[illegible]	[illegible]	[illegible]
5.30[d]	[illegible]	[illegible]	[illegible]	[illegible]

[d]Autocorrelatio[illegible]s reestimated with no such coef[illegible].

and prices received for all commodities. Thus, machinery and fuel and oil are estimated to be substitutes for farm labor. This is the relationship expected between these variables.

The estimated elasticity of demand for hired farm labor with respect to the farm wage rate, P_H, ranges between -0.25 and -1.5 (Table 5.5). If those models with very unstable coefficients are excluded, the range is narrowed to -0.9 to -0.25. And if model (5.27) is excluded since the P_H/P_R variable has an approximate t-value of -1.1, the range of the elasticity is -0.9 to -0.6. These values are still inelastic. Elasticity values of this magnitude mean that if farm wage rates rise ten percent, hired farm labor demand may drop from six to nine percent.

This elasticity of demand is higher than previous studies have found. Johnson and Heady (1962) estimated hired farm labor demand functions for several time periods. Their estimates of demand elasticity increased as the time period became more recent with the 1940-57 period estimates as high as -0.6. Heady and Tweeten (1963) analyzed data from 1926 through 1959 excluding 1942 through 1945 and estimated the elasticity to be -0.2 to -0.4.

Table 5.4. Continued

Model	Q_{Mt}	T	Q_{Ht-1}	ρ
5.20		-14 (13)		.58 (.19)
5.21		42 (19)		.17 (.30)
5.22		46 (17)		.22 (.31)
5.23		33 (13)	.10 (.35)	.61 (.24)
5.24		30 (18)		.31 (.24)
5.25		50 (23)		.41 (.27)
5.26	-.0007 (.0003)	92 (25)		.44 (.17)
5.27		50 (14)		-[d]
5.28[d]		.05 (.02)		.63 (.15)
5.29[d]		.03 (.02)	.41 (.32)	.46 (.24)
5.30[d]		.003 (.016)		.40 (.24)

[d]Autocorrelation is insignificant so the model is reestimated with no such coefficient.

and prices received for all commodities. Thus, machinery and fuel and oil are estimated to be substitutes for farm labor. This is the relationship expected between these variables.

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Table 5.5. Estimated elasticities of demand for hired farm labor with respect to prices and other variables, selected models[a]

Calculated from model:	$\frac{P_H}{P_{Rt}}$	$\frac{P_{fo}}{P_{Rt}}$	$\frac{P_M}{P_{Rt}}$	Q_{Ft}	N_t	A'_t	Y_{AFt-1}	V_{t-1}	Q_{Mt}
5.20	-1.07		.67				.05	.008	
	(.26)		(.17)				(.14)	(.017)	
5.22[b]	-.81	.41		.81					
	(.27)	(.19)		(.30)					
5.24	-.89	.37			.61				
	(.22)	(.19)			(.34)				
5.25	-.61	.16				-1.55			
	(.30)	(.19)				(.74)			
5.26	-.89	.34		1.36					-.19
	(.19)	(.14)		(.23)					(.09)
5.27[b]	-.27	.86		1.42					
	(.23)	(.23)		(.37)					
5.28[c]	-.54	.21		1.54					
	(.20)	(.21)		(.50)					
5.30[c]	-1.47	.48			.61				
	(.59)	(.34)			(1.20)				

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Model (5.22) has an unstable autocorrelation coefficient which is dropped for model (5.27).

[c]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

Heady and Tweeten offer several reasons for this increase in labor mobility over time. Some of their reasons are still valid and may explain why the estimates in this study are higher than their studies. The present data set spans two wars when the draft was effective but not on the scale of WWII, so this would not have as great an effect in this analysis. The time period 1940 to 1957 covers two periods of high national employment in the U.S. The period 1946 to 1977 covers the high national employment in the late fifties and sixties but also spans a major recession in the early seventies, so the effect of high employment is mixed with the effect of high unemployment. Increasing education and skills of workers will increase their mobility between the farm and nonfarm sectors of the economy. Improved communications and transportation may also increase mobility. Also, the elasticity may be increasing due to the same absolute change in the number of workers causes a larger percentage change as the total number of workers declines.

The elasticity of hired farm labor demand with respect to the price of machinery is estimated to be about 0.7 in model (5.20). But this value may be affected by the unstable coefficients on income and income variation in that model. The response in hired labor demand is estimated to be inelastic with respect to the price of machinery. The percentage change in the demand for hired farm labor will be less than the percentage change in machinery price.

The elasticity of hired farm labor demand with respect to the price of fuel and oil is inelastic also. Estimates from this study range from 0.16 to 0.86. Excluding the estimates from models containing unstable coefficients the elasticity is estimated to be 0.41. Thus if the price of fuel and oil rises by ten percent, the demand for hired farm labor is estimated to rise by about four percent over a period of a few years.

Since the index of prices received for all commodities is the numerator in the price ratios in the models, the elasticity of demand for hired farm labor with respect to the prices received can be estimated by summing the elasticities of all price ratios and changing the sign. Excluding the models with unstable coefficients, this elasticity is estimated to be between 0.3 and 0.55. So if the prices received for all commodities increased by ten percent and all other conditions remained the same, the demand for hired labor would increase by three to five and one-half percent in a few years. These estimates of elasticity are higher than the estimates in the Johnson and Heady (1962) study. They show the elasticity of demand with respect to prices received to be increasing over time. Better education and skills for workers and improved communication and transportation help explain this increase in mobility over time.

The demand for hired farm labor is positively correlated with the demand for family farm labor. The elasticity of hired labor demand with respect to family labor demand ranges from 0.8 in model (5.22) to 1.54 in model (5.28). Hence, a ten percent fall in family labor demand will trigger an eight to fifteen percent fall in hired labor demand. These estimates seem to contradict the figures in Table 5.2 because in actual numbers the level of family employment has fallen faster than the level of hired employment. However, in actual numbers ten percent of the family labor force in 1977 is about twenty-two percent of the hired labor force so the contradiction disappears. However, the elasticity suggests that family employment will continue to be greater than the demand for hired labor.

Models (5.24) and (5.25) estimate the explanatory power of the total number of U.S. farms and the average number of acres per farm in the U.S. Since all other variables are the same the lower mean square error for (5.25) indicates that the average size explains hired labor demand better than the total number of farms. Hired demand is estimated to be inelastic with respect to the number of farms and elastic to the average size. A ten percent fall in the number of farms is estimated to cause a six percent fall in hired labor demand over time. As farms are consolidated the number of hired workers is estimated to decline at a less than one-to-one relationship.

A ten percent increase in average farm size is estimated to cause a fifteen and one-half percent fall in hired labor demand after a few years. This elastic response is mainly due to the machinery-labor trade-off as acreage increases. As the farm size increases the stock of machinery may increase proportionately more than the number of workers. Model (5.30) is not used because of instability in some coefficient estimates.

In model (5.20) net farm income and the variance between expected and actual net farm income have positive but unstable coefficients. This condition is present in other unreported hired farm labor demand models.

Farmers' expenditures on machinery in the current year has a significant impact upon hired labor demand; the stock of machinery does not. The coefficient on the machinery stock variable in model (5.21) is positive but unstable. In model (5.26) the substitution of machinery for labor is quantified. A ten percent increase in machinery purchases is estimated to cause only a two percent decrease in the demand for hired labor.

Past hired labor demand has little effect on current demand. In models (5.23) and (5.29) the coefficient on the lagged demand is less than one-half and fairly unstable. Hired farm labor can then be considered as more dependent upon current variables than upon last year's demand level. The Johnson-Heady (1962) study shows this beginning to happen in their analysis of hired labor demand using different time periods. Their results show the more recent years with smaller coefficients on the lagged variable and increased instability of that coefficient than when a longer series of data is used.

Without a lagged demand variable included, long-range coefficients cannot be calculated as described earlier in this chapter (equation 5.3). But the response to changes in explanatory variables cannot be expected to be instantaneous. The estimated effects upon hired farm labor demand may take two to three years to complete and may be altered by future changes before completed.

These are the parameter estimates of hired farm labor demand. Family farm labor is analyzed in the next section.

Family farm employment

The distinction between demand for and supply of family farm labor is difficult to perceive. For this reason the models of family labor evaluated in this study are viewed as models of family farm labor employment and not necessarily models of demand or supply.

Family farm employment is hypothesized as a function of the relative returns from nonfarm and farm occupations, the unemployment rate, the level of hired labor employment, the number and size of farms, farmers' equity, national net farm income, the stock of machinery, and slowly changing variables accounted for by a time variable. Several models are developed to test hypotheses and to estimate the quantitative effects of these variables upon the level of family farm employment.

The number of family farm workers is estimated to decrease as the nonfarm wage rate increases relative to the farm wage rate (Table 5.6). Also, the national unemployment rate is estimated to have a positive effect; as unemployment increases the number of family workers employed on the farm is estimated to increase. Both of these responses are expected; however, the responses are fairly inelastic (Table 5.7).

The short-run elasticity of family farm employment with respect to the nonfarm to farm wage ratio is estimated to be -0.3 and from -0.54 to -0.65 in the long-run using models (5.32), (5.34), (5.35), and (5.36). The elasticity is estimated to be -0.4 in model (5.38) and -0.5 in models (5.31) and (5.37). The elasticity estimate is lower when the model is estimated using logarithmic data. Models (5.39) and (5.40) estimate the elasticity to be about -0.15.

Table 5.6. Estimates of structural coefficients for family farm employment[a]

Model	s^2	$\hat{R}^{2}$[b]	Intercept	Y_{Rt-1}
5.31[c]	10,453	1.000	15,447 (1,227)	-1,266 (266)
5.32	7,643	1.000	7,643 (1,984)	-813 (241)
5.33	6,852	1.000	1,182 (959)	
5.34	6,052	1.000	8,791 (2,113)	-793 (206)
5.35	6,734	1.000	8,923 (1,668)	-828 (238)
5.36	6,088	1.000	7,395 (1,672)	-782 (206)
5.37[d]	6,781	1.000	13,041 (1,222)	-1,212 (219)
5.38[d]	6,841	1.000	13,134 (1,191)	-1,055 (410)
5.39[d,e]	.00016	1.000	7.76 (.57)	-.16 (.07)
5.40[d,e]	.00017	1.000	7.76 (.51)	-.15 (.07)
5.41[e]	.00023	1.000	3.91 (1.02)	-.05 (.06)
5.42[c,f]	15,293	.992	12,481 (1,081)	-518 (177)

[a]Unless noted, OLS procedures are used to estimate the parameters of the models.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]This model is estimated using the AUTOREG procedure described by Barr, Goodnight, Sall, and Helwig (1976).

[d]Estimated using MLIML estimators with $\alpha = 1$.

[e]Estimated using data in logarithmic form except time.

[f]Y_R is the ratio of nonfarm to farm annual income in model (5.42).

UY_{Rt-1}	Q_{Ht}	N_t	A'_t	E_t	Y_{AFt-1}
3,559				144	
(911)				(39)	
2,118				69	
(827)				(31)	
1,090		.90			
(669)		(.14)			
1,921			-4.8	54	
(793)			(4.4)	(31)	
2,482					.018
(798)					(.012)
2,062				67	
(784)				(29)	
1,249	1.03			51	
(979)	(.32)			(39)	
1,537	.83			57	.01
(1,083)	(.47)			(41)	(.02)
.02	.34			-.03	
(.01)	(.09)			(.07)	
.02	.38			.06	
(.01)	(.07)			(.06)	
.02				.11	
(.01)				(.05)	
4,880				201	
(1,721)				(43)	

Table 5.6. Continued

Model	S_M	T	Q_{Ft-1}	ρ
5.31[c]	.02 (.01)	-158 (10)		.32 (.17)
5.32	.002 (.008)	-72 (19)	.52 (.10)	-[g]
5.33		-24 (12)	.33 (.12)	-[g]
5.34		-57 (19)	.43 (.13)	-[g]
5.35		-87 (18)	.50 (.10)	-[g]
5.36		-69 (16)	.53 (.08)	-[g]
5.37[d]		-127 (12)		.50 (.18)
5.38[d]		-132 (14)		.48 (.21)
5.39[d,e]	.03 (.03)	-.03 (.002)		.47 (.17)
5.40[d,e]		-.03 (.001)		.48 (.13)
5.41[e]		-.012 (.003)	.61 (.10)	-[g]
5.42[c,f]	.01 (.01)	-143 (10)		.33 (.17)

[g]The autocorrelation coefficient is not estimated for these models. The coefficients are estimated using the original data.

Table 5.7. Estimated elasticities of family farm employment with respect to prices and other variables and critical unemployment levels[a].

Calculated from model:	Y_{Rt-1}	UY_{Rt-1}	Q_{Ht}	N_t	A'_t	E_t	Y_{AFt-1}	S_{Mt}	$\hat{V}$[b]
5.31	-.49	.07				.21		.09	.36
	(.10)	(.02)				(.06)		(.04)	
5.32[c]	-.31	.04				.10		.01	.38
	(.09)	(.02)				(.05)		(.03)	
5.33[c]		.02		.70					
		(.01)		(.11)					
5.34[c]	-.31	.04			-.28	.08			.41
	(.08)	(.01)			(.26)	(.05)			
5.35[c]	-.32	.05					.06		.33
	(.09)	(.02)					(.04)		
5.36[c]	-.30	.04				.10			.38
	(.08)	(.01)				(.04)			
5.37	-.47	.02	.35			.07			.97
	(.08)	(.02)	(.11)			(.06)			
5.38	-.41	.03	.28			.08	.03		.69
	(.16)	(.02)	(.16)			(.06)	(.06)		
5.39[d]	-.16	.02	.34			-.03		.03	-[e]
	(.07)	(.01)	(.09)			(.07)		(.03)	
5.40[d]	-.15	.02	.38			-.06			-[e]
	(.07)	(.01)	(.07)			(.06)			
5.41[c,d]	-.05	.02				.11			-[e]
	(.06)	(.01)				(.05)			
5.42[f]	-.13	.06				.29		.05	.11
	(.04)	(.02)				(.06)		(.05)	

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data.

[b]The estimate of the critical unemployment level is the ratio of the coefficient on Y_R to the coefficient on $(UY_R)_{t-1}$ multiplied by -1.0. See model (5.9).

[c]These elasticities are short-term. Using an adjustment model as in (5.3), the long-term elasticities can be estimated.

[d]Models are estimated in logarithmic form; elasticities are estimated directly as the model coefficients.

[e]Model (5.9) is inappropriate to models using logarithmic data.

[f]Y_R is the ratio of nonfarm to farm annual income in model (5.42).

In the study by Heady and Tweeten (1963), the ratio of nonfarm to farm annual income is used. The ratio of nonfarm to farm hourly wage rates is not used in their analysis. In this analysis the wage ratio does a better job of explaining family farm employment than does the income ratio. Model (5.42) is similar to model (5.31) except the nonfarm to farm income ratio is used; the mean square error is larger in model (5.42) than in (5.31). Since the mean square error is smaller with it, the nonfarm to farm wage ratio is used more in this study.

The critical national unemployment rate is the level at which family labor starts to come back to agriculture from nonfarm jobs. This can be estimated as in model (5.9). This value is calculated by dividing the coefficient on the wage or income ratio, Y_R, by the coefficient on the product of the national unemployment rate and the wage or income ratio, (UY_R), and multiplying by -1.0. When using the wage ratio the calculated critical unemployment rates range from 0.33 to 0.41 excluding models (5.37) and (5.38); these seem unrealistically high. In model (5.42) which uses the income ratio, the critical unemployment rate is estimated to be 0.11; thus, if the national unemployment rate is greater than eleven percent there is estimated to be an increase in family farm employment due to lose of jobs in the nonfarm sector.

Although it is a small effect, the substitution of machinery for labor can be seen in the negative coefficient on current machinery expenditures. The stock of farm machinery does not have a significant effect estimated.

National net farm income and the variation in net farm income are estimated to have no significant effect upon the demand for hired farm labor. Past hired labor forces are estimated to have little effect upon current demand.

Since it is hard to distinguish between the demand for and the supply of family farm labor, the analysis estimates the effects of various factors upon family farm employment. The distinction is difficult because demand and supply decisions are made by the same people.

The number of family farm workers is estimated to decrease as the nonfarm wage rate increases relative to the farm wage rate. The unemployment rate has a positive effect estimated indicating difficulty to move to nonfarm jobs if the unemployment rate is high enough. The ratio of nonfarm to farm wage rates explains family farm employment better than the ratio of nonfarm to farm annual incomes.

The number and size of farms are estimated to have significant, positive and negative effects, respectively, upon family

The hired farm labor force does have a positive correlation with family farm employment. The response is estimated to be inelastic. This relationship is probably not so much a cause and effect relationship but more of two effects responding to the same stimuli.

The number and size of farms have significant effects upon employment. The number of farms is estimated in model (5.33) to have a positive effect that is inelastic in the short-run and unitary in the long-run. The average acreage per farm is estimated in model (5.34) to have a negative, inelastic effect on employment in both the short-run and the long-run. A one percent increase in average farm size is estimated to cause a decrease in family employment of 0.3 percent in the short-run and one-half percent in the long-run.

The inclusion of the number of farms causes the coefficients on the wage ratio and the equity ratio to become unstable. Model (5.33) is estimated without these two variables. Model (5.34) has a lower mean square error than model (5.33), thus model (5.34) is considered a better indicator of family farm employment than model (5.33).

The farmers' equity ratio and national net farm income have positive, but small, significant influences on family employment. In preliminary work the variation in net farm income was found to have insignificant effects and was not specified in the models analyzed here.

The stock of farm machinery is estimated to have a positive but small and not consistently significant effect upon family farm labor. Other, slowly changing variables have a significant negative effect on family employment over time.

However, the mobility of family labor has not increased to the point that past levels do not affect current levels. The lagged level of family farm employment is estimated to have a positive, significant effect upon the current level. In most cases the mean square error is improved when the lagged variable is specified in the model.

This concludes the analysis of family farm employment. A short summary ends the chapter.

Summary

The downward trends of farm population and employment have been of concern to people in and out of farming for years. In this chapter farm labor demand and employment are analyzed for the effects of various variables.

Farm labor demand and employment is hypothesized to be a function of net farm income, the variation in net farm income, the farm wage rate, the ratio of the nonfarm wage rate to the farm wage rate, the ratio of nonfarm to farm annual income, the prices of fuel and oil and machinery, all prices received by farmers, the number and size of farms, the ratio of farmers' equity to outstanding debt, the current stock of and expenditures for farm machinery, and other, slowly changing variables represented by a time variable. The demand for hired farm labor is hypothesized to be a function of the level of family farm employment. The level of family employment is hypothesized to be a function of the hired farm labor force, as well.

These variables are used to formulate several models of hired farm labor demand and family farm employment. These models are estimated within a system unless the specification includes no other endogenous variables. Data is from 1946 to 1977 and 1945 for lagged variables.

Hired farm labor demand is estimated to respond inelastically to changes in the farm wage rate. Hired labor demand is estimated to be inelastic with respect to both machinery and fuel and oil prices and to all prices received by farmers. These elasticity estimates are higher than in previous studies; increasing education and skills and improved communications and transportation may have increased farm workers' mobility between farm and nonfarm jobs.

Demand for hired labor is estimated to decrease as the number of farms decreases and as the size of farms increases.

Including the average acreage in the demand models gives a lower mean square error than with the number of farms.

Although it is a small effect, the substitution of machinery for labor can be seen in the negative coefficient on current machinery expenditures. The stock of farm machinery does not have a significant effect estimated.

National net farm income and the variation in net farm income are estimated to have no significant effect upon the demand for hired farm labor. Past hired labor forces are estimated to have little effect upon current demand.

Since it is hard to distinguish between the demand for and the supply of family farm labor, the analysis estimated the effects of various factors upon family farm employment. The distinction is difficult because demand and supply decisions are made by the same person.

The number of family farm workers is estimated to decrease as the nonfarm wage rate increases relative to the farm wage rate. The unemployment rate has a positive effect estimated indicating difficulty to move to nonfarm jobs if the unemployment rate is high enough. The ratio of nonfarm to farm wage rates explains family farm employment better than the ratio of nonfarm to farm annual incomes.

The number and size of farms are estimated to have significant, positive and negative effects, respectively, upon family employment. The average acreage explains the employment level better than the number of farms. Both effects are small, however.

The equity ratio and national net farm income are estimated to have small but significant positive effects upon family employment. The stock of farm machinery is estimated to have a small positive, but not consistently significant effect.

Other, slowly changing variables have a significant, negative effect. Lagged family employment has a significant effect on current employment.

The analysis of hired farm labor demand and family farm employment includes their effect upon each other. In both analyses, the other had a significant, positive effect. For family employment other model specifications yield lower mean square errors. In the analysis of hired labor demand, the level of family employment is included in the final demand specification. This relationship is not a true cause and effect relationship but more likely to be two complements moving together over time in response to other stimuli.

This concludes the analysis of the structural coefficients of agricultural labor resources. In the next chapter the demand for operating inputs in aggregate and for several specific inputs is analyzed.

CHAPTER VI. DEMAND FOR OPERATING INPUTS IN U.S. AGRICULTURE

Operating inputs are those agricultural resources which are used up in one production period. Machinery and equipment are used and worn but are left for another job. Labor may need rest and pay but the workers will be ready for more work. But resources such as fertilizer, fuel, feed, pesticides, etc., are used up in one production period and must be purchased in future production periods.

The proportion of inputs purchased from nonfarm suppliers has increased greatly in the past few decades (Table 6.1). Thus, the farmer of today is more vulnerable to input and output market conditions and fluctuations than the farmer of two generations ago. Since they are purchased each production period, demand and usage levels of operating inputs will fluctuate quickly to changes in prices and other variables thus affecting the final production level. This effect and the increasing use of purchased inputs makes farmers' reactions to changes of interest to policy makers as well as producers and suppliers of operating inputs.

Measured in 1967 dollars expenditures for operating inputs have increased since 1945 (Table 6.2). In aggregate, operating input purchases are 160 percent greater in 1977 than 1945 levels. The mixture of this aggregate measure has changed also. Purchases of fuel and oil for farm use have increased by 122 percent during this same period; electricity, by 1,848 percent. Seed purchases rise by 104 percent in the 1945-77 period; fertilizer and lime, by 300

Table 6.1. Indexes of total agricultural input, purchased and non-purchased, 1910-1977, selected years[a]

Year	Total input	Non-purchased input	Purchased input
		(1967 = 100)	
1910	86	158	38
1920	98	180	43
1930	101	176	50
1940	100	159	58
1945	103	161	62
1950	104	150	70
1955	105	143	76
1960	101	119	86
1965	98	103	93
1970	100	97	102
1975	100	92	107
1977	103	88	118

[a]Source: (Durost and Black, 1978, p. 56-57).

Table 6.2. Expenditures for operating inputs in aggregate and by type, 1945-1977, selected years[a]

Year	All	Fuel & oil	Electricity	Seed	Fertilizer & lime	Pesticides	Feed
				(million 1967 dollars)			
1945	10,504	907	25	537	842	79	3,380
1950	12,126	1,437	52	534	1,037	152	3,316
1955	14,024	1,594	104	566	1,173	165	3,880
1960	17,435	1,508	176	583	1,344	256	4,948
1965	20,551	1,609	236	720	1,936	479	5,849
1970	24,857	1,608	310	828	2,716	957	7,949
1975	24,484	1,879	422	936	2,941	1,102	6,763
1977	27,448	2,018	487	1,094	3,364	1,212	7,441

[a]Calculated from data in (U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service, (1978, p. 43)

percent; and pesticides, by 1,434 percent. Feed purchases in 1977 were 120 percent greater than the 1945 level.

These increases in the use of operating inputs have been caused partially by changes in prices. The aggregate price of operating inputs relative to all prices received by farmers has remained fairly stable (Figure 6.1). The prices of labor, machinery, and farmland have shown a steady increase relative to all prices received. The high crop prices of the early 1970's cause the drop in the relative prices for those years.

The prices of individual operating inputs have changed differently from the aggregate price. This partially explains the divergence in usage levels. The price of fuel and oil has increased slightly relative to all prices received by farmers (Figure 6.2). However the fuel and oil price has declined relative to the farm wage rate explaining some of the substitution between fuel and labor for farmwork. The price of electricity has fallen relative to the prices received by farmers.

The price of seed has increased relative to prices received by farmers for crops considerably more than the prices of fertilizer and lime and pesticides (Figure 6.3). The past few years have caused considerable variation. But the trends of seed prices increasing and pesticide prices decreasing relative to crop prices received by farmers are discernible. The future path of fertilizer and lime prices relative to crop prices is difficult to predict from the graph. The price of feed relative to prices received for

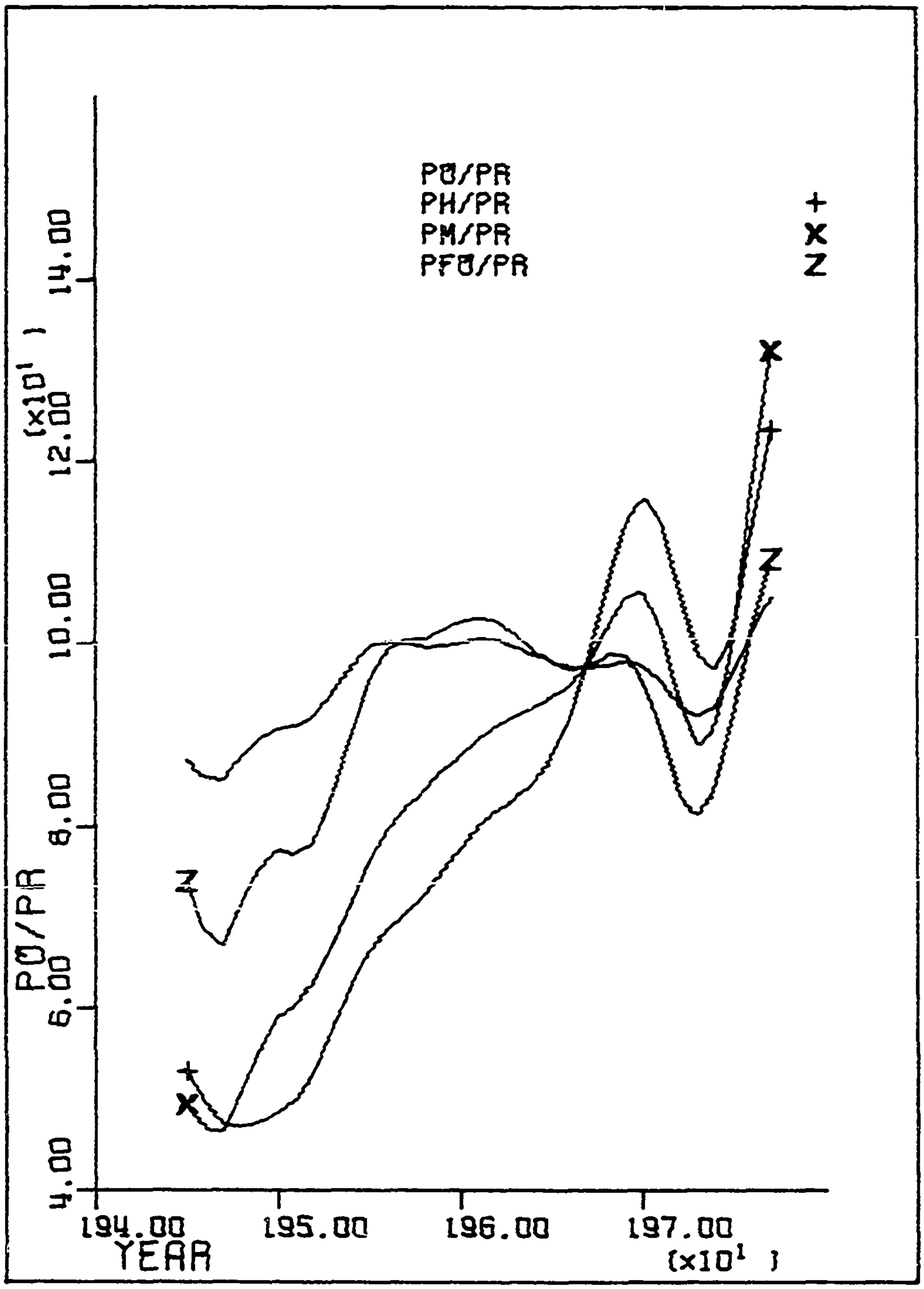

Figure 6.1. Indices of the aggregate operating input price, the farm wage rate, the machinery price, and the fuel and oil price relative to all prices received by farmers, P_O/P_R, P_H/P_R, P_M/P_R, and P_{fo}/P_R, respectively, 1945-1977.

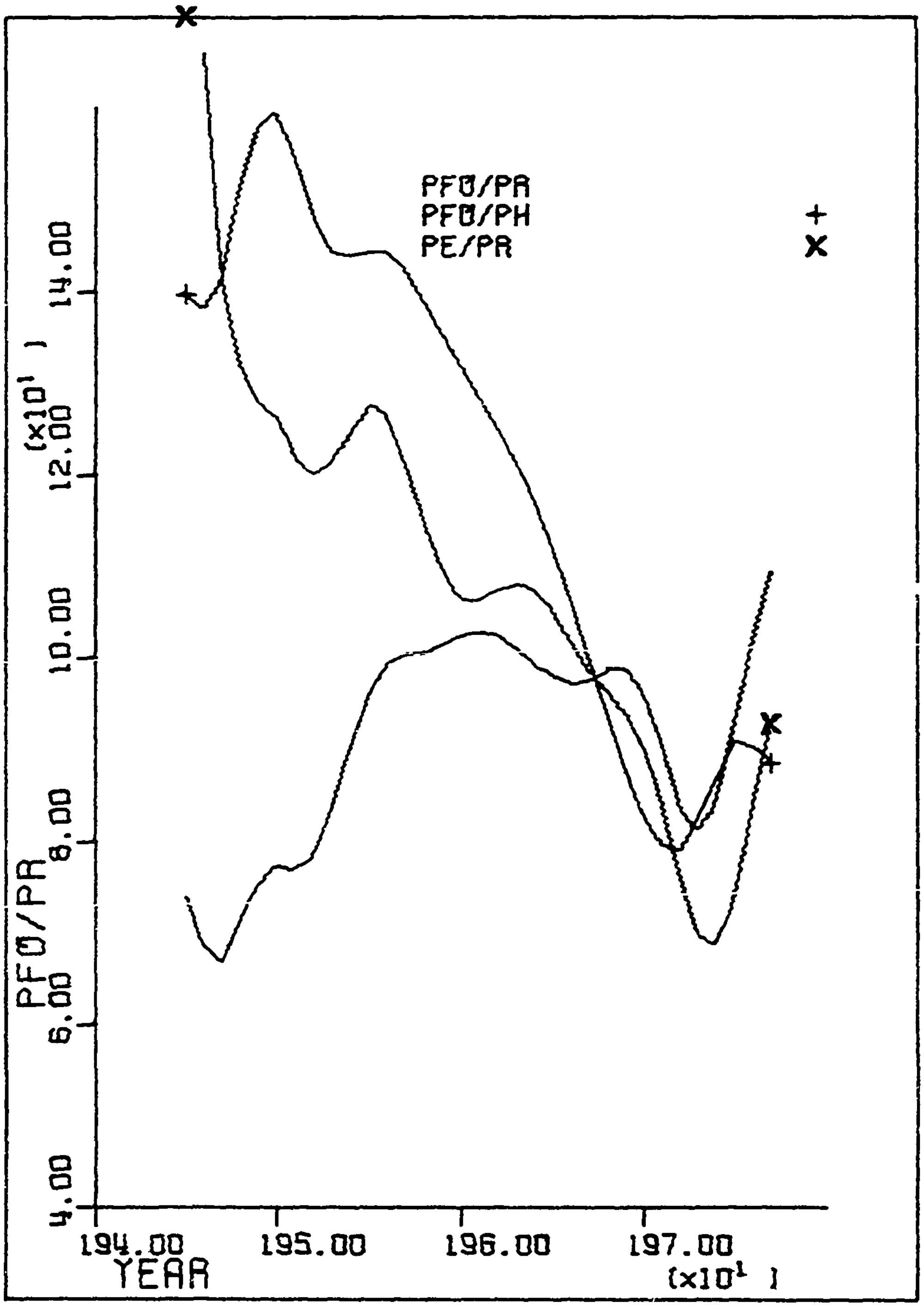

Figure 6.2. Indices of the price of fuel and oil relative to all prices received and the farm wage rate, P_{fo}/P_R and P_{fo}/P_H, respectively, and the price of electricity relative to all prices received by farmers, P_e/P_R, 1945-1977.

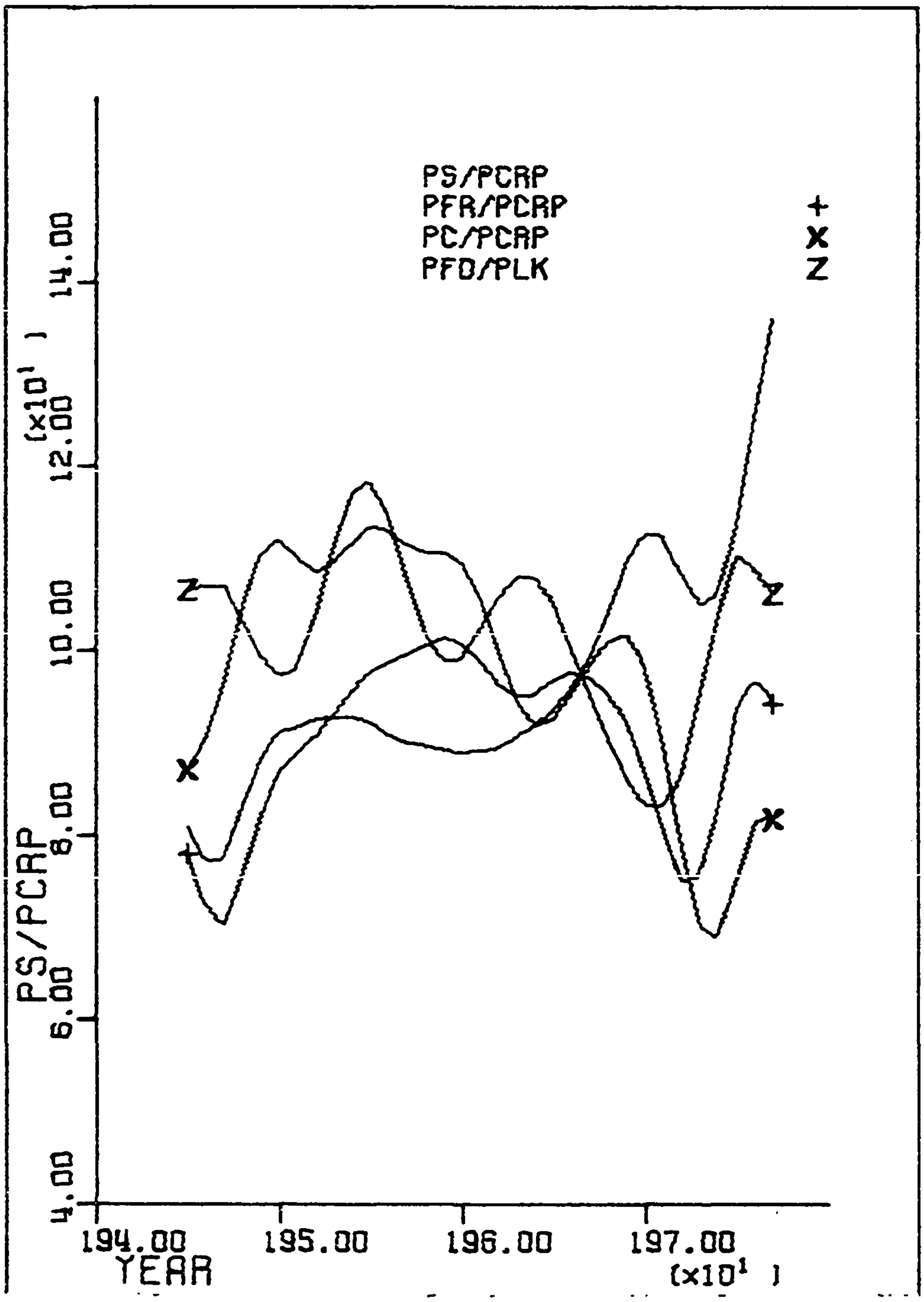

Figure 6.3. Indices of the prices of seed, fertilizer and lime, and pesticides relative to crop prices received by farmers, P_S/P_{CRP}, P_{fr}/P_{CRP}, and P_C/P_{CRP}, respectively, and the price of feed relative to livestock prices, P_{fd}/P_{LK}, 1945-1977.

livestock has varied considerably in this time period but no long-term trend is observable.

The relationship between expenditure changes and prices and other variables is what this analysis estimates. The importance of these price changes upon expenditure levels is estimated for operating inputs. The influence of other variables such as the equity ratio, net farm income, and farm size and number is also estimated.

All operating inputs are grouped together for one part of the analysis. The analysis also breaks the aggregate measure into expenditures on fuel and oil, electricity, seed, fertilizer and lime, pesticides, and feed. The estimation results are presented after a short section covering the development of demand models for operating inputs.

Models of Operating Input Demand

Operating inputs have the simplest models of demand. The models are straightforward functions of prices and other variables. Stocks are quite small due to annual purchases of quantities needed for that production period, so stocks do not affect operating input demand as machinery stocks affect machinery demand. Thus, the reaction of operating input demand to price changes is quicker than the reaction of machinery demand.

The human element involved in labor is missing from operating input demand. Thus, demand for the latter inputs is hypothesized to react quicker to changes than labor.

As more technology and inputs manufactured off-farm are used, agricultural inputs become less dissimilar to those used in non-farm industries. This increases the direct competition for inputs and means the input price equates or approximately equates the marginal values of the input in farm and nonfarm uses.

Demand for operating inputs can be expressed as an adjustment process. The hypothesis that it reacts quicker than labor and machinery demand can hold and operating input demand still take some time to adjust to variable changes. Institutional, physical, psychological, and other reasons may keep a farmer from adjusting purchases instantaneously as prices and other variables change. Uncertainty of future changes and lack of knowledge of the production function and its uses can cause operating demand to be fairly static in the short-run. Hence, an adjustment model such as Model J in Chapter II can be used in the analysis of operating input demand.

Operating input demand is hypothesized to be a function of several variables. The prices of the input itself and its substitutes and complements will influence input demand as will the prices received for the products. As farm size increases, capital replaces labor to some degree and management techniques increase the use of some inputs over others, e.g., pesticide use increases while mechanical cultivation declines. Average farm size and the number of farms, since the total cropland acreage in the U.S. does not change rapidly, can estimate input substitutions and, hence, demand shifts.

It is difficult to hypothesize a priori the effect upon input demand of changes in the ratio of farmers' equity to outstanding debt. Since operating inputs are consumed and not added to existing stocks, the effects of changes in the equity ratio is hard to determine. Perhaps as the equity ratio declines due to machinery purchases, demand for operating inputs will increase so that returns to durable resources (e.g., machinery) may increase.

Annual net farm income is expected to have a positive influence upon input demand. Variation between expected and actual farm income should have a negative influence; as the variation increases farmers' are less willing to extend their purchases and perhaps suffer a loss. The demand for feed is expected to be directly influenced by the level of national personal disposable income; higher incomes create demand for more meat in the diet which creates demand for more livestock and thus, feed.

In preliminary analysis, the inclusion of a dummy variable for government income support programs produced some curious results. From 1972 to 1974 there were no government programs in effect; in this period net farm income and crop prices were very high due to many factors. Consequently, investments in durable resources and purchases of other inputs increased in this time period. Hence, the estimated effect of government income support programs is negative. Since it appears to be measuring the large variances of the 1972-74 period rather than just the impact of government programs, the government dummy variable is dropped from further analysis.

Many other, slowly changing variables may influence the demand for operating inputs. These are incorporated into the time variable.

These variables are used to delineate several demand models. They are not used together in one model necessarily. The model for the optimal level of aggregate operating input demand, Q^*_{ot} is similar to (2.16):

$$Q^*_{ot} = a + b(P_O/P_R)_t + c(P_H/P_R)_t + dA'_t + eS_Mt + fT + u_t \tag{6.1}$$

which specifies demand as a function of the aggregate price, P_O, and the farm wage rate, P_H, relative to the prices received, P_R; the average farm size, A'; the stock of farm machinery, S_M; and slowly changing variables incorporated into the time variable, T. Model (6.1) may be used as it is with the actual level of aggregate operating input expenditures substituted for the desired level.

Actual adjustments in the usage level of operating inputs in the current year is assumed to be a constant proportion of the difference between the desired level in the current year and the actual purchases during the past year:

$$Q_{ot} - Q_{ot-1} = g(Q^*_{ot} - Q_{ot-1}) \tag{6.2}$$

By substituting model (6.1) into (6.2) an adjustment model similar to Model J in Chapter II is developed:

$$Q_{ot} = ag + bg(P_o/P_R)_t + cg(P_H/P_R)_t + dgA'_t + egS_{Mt} + fgT + (1-g)Q_{ot-1} + gu_t \quad (6.3)$$

The long-run coefficients of (6.1) can be estimated from (6.3) by dividing the short-run coefficients in (6.3) by the adjustment coefficient, g, estimated from the lagged input purchase variable.

Alternative models can be formulated by substituting other variables for those in (6.1). Adjustment models can be developed for these as well. Models for specific operating inputs may differ in variable specification but not in form. The models used are specified in the results section following the systems of models.

These models of demand for operating inputs are assumed to be part of an interdependent system of resource markets. The basic system for operating inputs in aggregate is specified below. (Variables are defined after all the systems are presented.)

$$Q_{ot} = f\left((P_o/P_R)_t,\ (P_H/P_R)_t,\ (P_{FL}/P_R)_t,\ N_t,\ E_t,\ T\right) \quad (6.4)$$

$$(P_o/P_R)_t = f\left(Q_{ot-1},\ T,\ (P_o/P_R)_{t-1}\right) \quad (6.5)$$

$$Q_{Ht} = f((P_H/P_R)_t, (P_o/P_R)_t, Q_{Ft}, S_{Mt}, T) \tag{6.6}$$

$$Q_{Ft} = f(Y_{Rt-1}, (UY_R)_{t-1}, Y_{AFt-1}, T, Q_{Ft-1}) \tag{6.7}$$

$$(P_H/P_R)_t = f(Q_{Ht}, T, (P_H/P_R)_{t-1}) \tag{6.8}$$

$$(P_{FL}/P_R)_t = f((P_M/P_R)_t, (P_H/P_R)_t, E_t, T) \tag{6.9}$$

$$(P_M/P_R)_t = f(Q_{Mt}, (P_H/P_R)_t, P_{Nt}, T, (P_M/P_R)_{t-1}) \tag{6.10}$$

$$Q_{Mt} = f((P_M/P_R)_t, (P_H/P_R)_t, Y_{AFt-1}, V_{t-1}, T, Q_{Mt-1}) \tag{6.11}$$

$$N_t = f((P_{FL}/P_R)_{t-1}, (P_H/P_R)_{t-1}, T, N_{t-1}) \tag{6.12}$$

The specific inputs of fuel and oil are treated together and are considered as substitutes of electricity. The basic system for fuel and oil and electricity is given here.

$$Q_{fot} = f((P_{fo}/P_R)_t, (P_M/P_R)_t, (P_H/P_R)_t,$$

$$A'_t, Y_{AFt-1}, V_{t-1}, T, Q_{fot-1}) \tag{6.13}$$

$$(P_{fo}/P_R)_t = f((P_e/P_R)_t, Q_{fot-1}, T, (P_{fo}/P_R)_{t-1}) \tag{6.14}$$

$$Q_{et} = f((P_e/P_R)_t, (P_H/P_R)_t, A'_t, Y_{AFt-1}, V_{t-1}, T, Q_{et-1}) \tag{6.15}$$

$$(P_e/P_R)_t = f(Q_{et-1}, T, (P_e/P_R)_{t-1}) \tag{6.16}$$

$$(P_H/P_R)_t = f(Q_{Ht}, T, (P_H/P_R)_{t-1}) \tag{6.17}$$

$$Q_{Ht} = f\left((P_H/P_R)_t,\ (P_{fo}/P_R)_t,\ Q_{Ft},\ S_{Mt},\ T\right) \tag{6.18}$$

$$Q_{Ft} = f\left(Y_{Rt-1},\ (UY_R)_{t-1},\ Q_{Ht},\ T,\ Q_{Ft-1}\right) \tag{6.19}$$

$$(P_M/P_R)_t = f\left((P_H/P_R)_t,\ (P_{fo}/P_R)_t,\ (P_H/P_R)_{t-1},\ P_{Nt},\ T,\ (P_M/P_R)_{t-1}\right) \tag{6.20}$$

$$A'_t = f\left((P_{FL}/P_R)_{t-1},\ (P_H/P_R)_{t-1},\ T\right) \tag{6.21}$$

$$(P_{FL}/P_R)_t = f\left((P_M/P_R)_t,\ (P_H/P_R)_t,\ E_t,\ T\right) \tag{6.22}$$

Since seed, fertilizer and lime, and pesticides are inputs in crop production, they are treated in a system together. The basic system for these crop inputs is presented below.

$$Q_{frt} = f\left((P_{fr}/P_{CRP})_t,\ (P_s/P_{CRP})_t,\ (P_C/P_{CRP})_t,\ E_t,\ Y_{AFt-1},\ T,\ Q_{frt-1}\right) \tag{6.23}$$

$$(P_{fr}/P_{CRP})_t = f\left(Q_{frt},\ Q_{frt-1},\ P_{Nt},\ T,\ (P_{fr}/P_{CRP})_{t-1}\right) \tag{6.24}$$

$$Q_{st} = f\left((P_s/P_{CRP})_t,\ (P_{fr}/P_{CRP})_t,\ (P_c/P_{CRP})_t,\ A'_t,\ Y_{AFt-1},\ V_{t-1},\ T,\ Q_{st-1}\right) \tag{6.25}$$

$$(P_s/P_{CRP})_t = f\left(Q_{st},\ Q_{st-1},\ (P_s/P_{CRP})_{t-1}\right) \tag{6.26}$$

$$Q_{ct} = f\left((P_c/P_{CRP})_t,\ (P_s/P_{CRP})_t,\ (P_{fr}/P_{CRP})_t,\ E_t,\ T,\ Q_{ct-1}\right) \tag{6.27}$$

$$(P_c/P_{CRP})_t = f(Q_{ct}, Q_{ct-1}, T) \tag{6.28}$$

$$A'_t = f\left((P_R/P_p)_{t-1}, Y_{AFt-1}, A'_{t-1}\right) \tag{6.29}$$

$$(P_R/P_p)_t = f\left(X_t, Y_{Dt}, T, (P_R/P_p)_{t-1}\right) \tag{6.30}$$

The demand for feed is treated by itself in a smaller system. The basic system for feed demand is described here.

$$Q_{fdt} = f\left((P_{fd}/P_{LK})_t, (P_{fd}/P_{LK})_{t-1}, N_t, E_t, Y_{Dt}, T\right) \tag{6.31}$$

$$(P_{fd}/P_{LK})_t = f\left(Q_{fdt}, T, (P_{fd}/P_{LK})_{t-1}\right) \tag{6.32}$$

$$N_t = f\left((P_R/P_p)_t, Y_{AFt-1}, N_{t-1}\right) \tag{6.33}$$

$$(P_R/P_p)_t = f\left(X_t, Y_{Dt}, T, (P_R/P_p)_{t-1}\right) \tag{6.34}$$

These basic systems are adapted for alternative demand models. The systems were designed around substitutes and complements using preliminary OLS estimations and some size considerations.

The variables in the systems just presented are defined here. The endogenous variables are presented first.

A' = the national average number of acres per farm in the U.S. on January 1 of the current year

N = the number of farms in the U.S. on January 1 of the current year

P_c = the index of the national average price of pesticides

P_{CRP} = the index of the national average, aggregate price received by farmers for crop products

Q_{fr} = U.S. farmers' total expenditures for fertilizer and lime for agricultural use

Q_H = the number of persons in the national hired farm labor force

Q_M = U.S. farmers' total expenditures for all farm machinery for farm use

Q_O = U.S. farmers' total expenditures for all agricultural operating inputs in aggregate

Q_S = U.S. farmers' total expenditures for seed for farm use

The exogenous variables are listed next. Two additional variables, TA and TSQ are also listed; they are not in the basic systems as specified but are used in later modifications.

E = the ratio of U.S. farmers' total equity to their total outstanding debt for farming purposes

P_N = the index of the national average hourly wage rate of all nonfarm, industrial workers deflated by the Consumer Price Index

S_M = the stock of farm machinery on farms on January 1 of the current year

T = the time variable which represents slowly changing variables and T = 47.0 for 1947

TA = the national acreage for crop production

TSQ = the squared value of the time variable, T

U = the national average unemployment rate, $0 \leq U \leq 1$

UY_R = the product of U and Y_R

V = the three-year simple average of variation between expected and actual national net farm income

X = the national value of net agricultural exports

P_e = the index of the national average price of electricity on farms

P_{FL} = the index of the average per acre value of all U.S. farmland

P_{fd} = the index of the national average price of feed

P_{fo} = the index of the national average price of fuel and oil on farms

P_{fr} = the index of the national average price of fertilizer and lime

P_H = the index of the national average farm wage rate

P_{LK} = the index of the national average, aggregate price received by farmers for livestock and livestock products

P_M = the index of the national average price of all farm machinery

P_o = the index of the national average, aggregate price of all agricultural operating inputs

P_p = the index of the national average, aggregate price paid by farmers for all resources

P_R = the index of the national average, aggregate price received by farmers for all commodities

P_s = the index of the national average price for agricultural seed

Q_c = U.S. farmers' total expenditures for pesticides for crop use

Q_e = U.S. farmers' total expenditures for electricity for farm use

Q_F = the number of persons in the national family farm labor force

Q_{fd} = U.S. farmers' total expenditures for feed for livestock use

Q_{fo} = U.S. farmers' total expenditures for fuel and oil for farm use

Y_{AF} = the three-year simple average of national net farm income

Y_D = personal disposable income for the entire population, farm and nonfarm, deflated by the Consumer Price Index

Y_R = the index of the ratio of nonfarm to farm national average hourly wage rates

The subscript t denotes the current year; t-1 denotes the year just passed. A more detailed description of these variables and the sources of data is in Appendix A.

The variables, models, and systems presented in this section are used to analyze the demand by farmers' for aggregate and specific agricultural operating inputs. The results of the analysis are presented in the next section.

Empirical Estimates of the National Demand Functions for Operating Inputs

Estimates of the parameters of the models just described are presented in this section. These results allow us to test hypotheses of directional effects on operating input demand of changes in explanatory variables. They also estimate the quantitative reaction of operating input demand to changes in prices and other explanatory variables. With these estimates the changes in operating input demand due to future trends and changes in U.S. agriculture can be estimated.

The estimation procedures used to estimate the models are described in Chapter III. Fuller's modified limited information maximum likelihood (MLIML) estimator with $\alpha = 1$ is used for the models as single equations within a system. The data used are from 1946 to 1977; for lagged variables data from 1945 is used as well.

The estimates of structural coefficients and elasticities for operating input demand in aggregate are presented first. The energy inputs of fuel and oil and electricity are then discussed. The estimates of demand for the crop production inputs of seed, fertilizer and lime, and pesticides are presented followed by the estimates for feed demand. A short summary closes the chapter.

Operating inputs in aggregate

Aggregate operating inputs measure the total level of expenditures on all operating inputs. To develop this aggregate measure, these inputs are grouped together: feed, seed, feeder livestock, fertilizer and lime, building repairs, fuel and oil, machinery repairs, pesticides, utilities, custom work, machine hire, ginning, interest on nonreal estate debt, and other miscellaneous supplies. These inputs are for farm use only. Those inputs analyzed individually are included in this aggregate measure.

Demand for aggregate operating inputs is hypothesized to be a function of the aggregate price of operating inputs, the price of farmland and machinery, the farm wage rate, the prices received by farmers for all products, the number and size of farms, the ratio of farmers' equity to outstanding debt, net farm income, the variation between expected and actual net farm income, and slowly changing variables incorporated into the time variable. With these variables various models are developed to test hypotheses and estimate the quantitative effects of changes in explanatory variables upon demand for operating inputs. Expenditures are measured in hundred million dollars at 1967 prices.

Changes in the aggregate price of operating inputs have opposite effects on operating input demand (Table 6.3). The elasticity of demand with respect to its own price is estimated to be near unity or greater (Table 6.4). In model (6.37) a lower elasticity is estimated but the model has a large mean square error. Excluding model (6.37) and others with unstable coefficients the elasticity is estimated to lie between -1.1 and -1.5. A ten percent rise in the aggregate price of operating inputs is estimated to cause an eleven to thirteen percent drop in aggregate demand for operating inputs.

Heady and Tweeten (1963) estimate the aggregate demand elasticity to be approximately -0.6 using least squares estimation. Using limited information and the average production function estimators, they find the elasticity to be -2.3 and -1.4 in the long-run. These estimates bracket the results of this study. As the purchased proportion of all inputs increases, the importance

Table 6.3. Estimates of structural coefficients of demand for aggregate operating inputs[a]

Model	s^2	$\hat{R}^2$[b]	Intercept	$\frac{P_o}{P_{Rt}}$	$\frac{P_o}{P_{Rt-1}}$	$\frac{P_H}{P_{Rt}}$
6.35	12.7	1.000	102	-95	-137	29
			(41)	(37)	(57)	(15)
6.36	19.0	1.000	-77	-63		46
			(114)	(100)		(24)
6.37	20.2	1.000	92	-192		
			(64)	(29)		
6.38	15.9	1.000	-63	-113		39
			(43)	(29)		(21)
6.39[c]	.0015	1.000	5.7	-1.5		-0.6
			(0.5)	(0.5)		(0.3)
6.40[c]	.0011	1.000	1.1	-1.2		-0.3
			(3.8)	(0.4)		(0.2)
6.41[c]	.0015	1.000	5.2	-.51		
			(0.6)	(.43)		
6.42[c]	.0010	1.000	2.6	.40		
			(4.7)	(.22)		

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or Appendix A for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

$\frac{P_{FL}}{P_{Rt}}$	$\frac{P_M}{P_{Rt-1}}$	N_t	A'_t	E_t	Y_{AFt-1}
	92			-1.8	
	(24)			(1.0)	
		.003			-.0001
		(.013)			(.0011)
50				-3.0	
(13)				(1.6)	
			.12		.0005
			(.18)		(.0008)
1.0				-.29	
(0.3)				(.11)	
0.5	.19		.77		-.04
(0.2)	(.16)		(.55)		(.14)
.49				-.18	
(.26)				(.12)	
		-.16		-.07	
		(.41)		(.11)	

Model	V_{t-1}	T	Q_{ot-1}	ρ
6.35		3.6		–[d]
		(0.4)		
6.36	-.0000002	3.7	.27	.05
	(.0000002)	(2.2)	(.53)	(.42)
6.37	-.0000004	4.3		–[d]
	(.0000001)	(0.7)		
6.38	-.0000004	4.6		–[d]
	(.0000002)	(1.1)		
6.39[d]	-.026	.009		–[d]
	(.011)	(.006)		
6.40[d]		.003		–[d]
		(.012)		
6.41[d]	-.005	.009		.35
	(.010)	(.010)		(.19)
6.42[d]	.004	-.001	.77	.08
	(.007)	(.008)	(.34)	(.26)

[d]Autocorrelation is insignificant so the model is reestimated with no such coefficient.

Table 6.4. Estimated elasticities of demand for aggregate operating inputs with respect to prices and other variables, selected models[a]

Calculated from model:	$\frac{P_o}{P_{Rt}}$	$\frac{P_o}{P_{Rt-1}}$	$\frac{P_H}{P_{Rt}}$	$\frac{P_{FL}}{P_{Rt}}$	$\frac{P_M}{P_{Rt-1}}$	A'_t	E_t	Y_{AFt-1}	V_{t-1}
6.35	-.49	-.70	.12		.40		-.07		
	(.19)	(.29)	(.06)		(.10)		(.04)		
6.37	-.98			.21			-.12		-.015
	(.15)			(.06)			(.06)		(.004)
6.38	-.58		.17			.20		.04	-.015
	(.15)		(.09)			(.29)		(.07)	(.007)
6.39[b]	-1.48		-.62	.96			-.29		-.026
	(.49)		(.33)	(.35)			(.11)		(.011)
6.40[b]	-1.17		-.30	.47	.19	.77		-.04	
	(.38)		(.24)	(.23)	(.16)	(.55)		(.14)	
6.41[b]	-.51			.49			-.18		-.005
	(.43)			(.26)			(.12)		(.010)

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

of prices is assumed to increase. Hence the more elastic response in this study when compared to Heady and Tweeten's least squares estimations is expected.

The effect of the farm wage rate upon demand is difficult to determine. Both negative and positive responses are estimated. Models (6.35) and 6.38) which use the data in original form predict a direct, but quite inelastic response. Models (6.39) and (6.40) which use logarithmically transformed data estimate the response to be inelastic but negative. The dilemma is not solved by eliminating models with very unstable coefficients. The elasticity of aggregate demand with respect to the farm wage rate is estimated to be -0.6 to 0.1.

The elasticity of demand for operating inputs with respect to the price of farmland is estimated to range from 0.2 to 1.0. The elasticity estimates are significant at a ninety percent level of confidence. A ten percent rise in farmland prices is estimated to cause an inelastic response of a two percent rise to an almost unity response of nine and a half percent rise in demand; the best estimate is 4.7 percent in model (6.40).

Last year's machinery price is estimated to cause direct shifts in operating input demand. The response is estimated to be inelastic. A ten percent rise in machinery prices this year is estimated to produce a four percent rise in operating input demand next year.

Operating input demand response to prices received is direct. The elasticity of demand to prices received is estimated to be 0.4 to 1.1; estimates from equations with fairly stable coefficient estimates range from 0.7 to 1.1. Thus, a ten percent rise in prices received by farmers is estimated to cause a seven to an eleven percent rise in aggregate demand for operating inputs.

In only one model did farm size or numbers have a significant effect upon aggregate demand for operating inputs. In model (6.40) the demand elasticity with respect to acres per farm is 0.77; however, the strength of this estimate is shaded by the coefficients on net farm income and time which are quite unstable.

As the equity ratio falls the demand for operating inputs in aggregate is estimated to rise significantly but inelastically. A ten percent fall in the equity ratio is estimated to cause a one to three percent increase in operating input demand.

Net farm income does not have a significant effect upon operating input demand as the estimates in this study show. The variation between expected and actual net farm income is estimated to have a significant, although small and inelastic, opposite effect upon demand for operating inputs.

In the models using the data in original form, slowly changing variables have a significant and positive effect on demand over time. However, using logarithmic data these variables had only one significant coefficient in model (6.39).

The lagged value of expenditures on operating inputs did not provide satisfactory responses in these demand models. In several cases such as model (6.36), the coefficient on the lagged variable was very unstable. In other cases such as model (6.42), including the lagged variable caused instability and wrong signs in the coefficients of other variables.

So far the analysis has been with operating inputs in aggregate. Now this aggregate measure is split into several components. First, the energy inputs of fuel and oil and electricity are analyzed; second the crop inputs of seed, fertilizer and lime, and pesticides; and third, feed.

Fuel and oil

Farmers' expenditures for fuel and oil include expenditures for crop and livestock enterprizes. Fuel and oil used in production, marketing, repairs, overhead, and other farm work is counted. Only fuel and oil used in and for farm business is counted. The fuel and oil used by automobiles for farm business is included.

Demand for fuel and oil by farmers is hypothesized to be a function of its own price, the prices of electricity and machinery, the farm wage rate, the prices received by farmers for all products, acres per farm, total cropland acreage, net farm income, variation between expected and actual net farm income, the stock of farm machinery, and slowly changing variables incorporated into the time variables. With these variables various models are developed to test hypotheses and to estimate the quantitative effects of these variables upon demand for fuel and oil.

From economic theory the demand for fuel and oil is expected to have a negative relationship with its own price; we expect the demand curve to be negatively sloped. Empirically, this was difficult to find. The coefficient on the fuel and oil price ratios is usually significant but positive (Table 6.5). In model (6.44) the fuel and oil coefficient is negative but the wage rate and the machinery price have coefficients with signs opposite of what is expected for substitutes and complements, respectively. Model (6.47) shows a negative relationship between demand and fuel and oil price but the autocorrelation coefficient is not significant. When model (6.47) is reestimated without the autocorrelation coefficient, the fuel and oil price coefficient becomes positive and the total acreage and net farm income coefficients become unstable. Model (6.48) shows a negative demand response to fuel and oil price changes but cannot be considered a demand function because it contains no other variables. This positive coefficient on the fuel and oil price persists when using the data in original form and in logarithmic form.

Over the past few decades the consumption of fuel and oil has been increasing even as its price has been increasing. Because

Table 6.5. Estimates of structural coefficients of demand for fuel and oil[a]

Model	s^2	$\hat{R}^2$[b]	Intercept	$\frac{P_{fo}}{P_{Rt}}$	$\frac{P_{fo}}{P_{Ht}}$
6.43	1,153	1.000	-377 (307)	332 (108)	
6.44	3,468	.998	1,281 (454)	-1,259 (931)	
6.45	3,858	1.000	-4,225 (1,279)		803 (650)
6.46	3,853	.997	-4,314 (3,144)		611 (478)
6.47	4,196	.998	-20,969 (7,175)		-1,217 (855)
6.48	9,243	.990	2,005 (213)		-373 (174)
6.49	5,094	.996	-1,109 (468)		1,044 (232)
6.50	1,781	.999	-11,339 (1,575)		
6.51[c]	.00049	1.000	.45 (.46)	.14 (.06)	
6.52[c]	.00136	1.000	-84 (16)		

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or Appendix A for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

$\frac{P_{fo}}{P_{Ht-1}}$	$\frac{P_e}{P_{Rt}}$	$\frac{P_H}{P_{Rt}}$	$\frac{P_M}{P_{Rt}}$	$\frac{P_M}{P_{Rt-1}}$	A'_t	TA_t
		-155			1.67	
		(111)			(1.32)	
		-1,367	2,566			
		(908)	(2,023)			
517					7.0	
(341)					(5.6)	
					-3.7	.002
					(4.7)	(.003)
						.018
						(.006)
				270		.009
				(145)		(.001)
	.18	-.17				
	(.07)	(.07)				
				-.14		6.43
				(.08)		(1.12)

Table 6.5. Continued

Y_{AFt-1}	V_{t-1}	S_{Mt}	T	TSQ	Q_{fot-1}	ρ
.017	.000002		-3.6		.78	-.38
(.006)	(.000002)		(9.7)		(.07)	(.22)
	.000004)	.016	-.1			.54
	(.000002)	(.007)	(12.3)			(.59)
.05	-.000009	.013	15.5			-.16
(.02)	(.000004)	(.008)	(26.1)			(.40)
			68.5			.61
			(32.2)			(.17)
.05				.69		.27
(.02)				(.12)		(.28)
						.78
						(.12)
				.37		.53
				(.05)		(.16)
.03				.51		.61
(.01)				(.06)		(.17)
.12	.006	.05	.012		.60	-.54
(.04)	(.005)	(.04)	(.003)		(.08)	(.25)
				.00034		.51
				(.00005)		(.17)

the data are national data, the level of consumption reflects the addition of new consumers and new technologies using fuel and oil as well as adjustment to current uses. Apparently the additional uses of fuel and oil have increased more than present uses have adjusted to fuel and oil price rises. While we cannot experiment and relive economic history, we can postulate that the level of consumption of fuel and oil may have risen to greater levels if the price had not risen. The individual farmer will adjust to prices, but because these are national data this adjustment is lost amidst the influx of new technologies.

By excluding the fuel and oil price, the mean square error is improved in model (6.50). The lagged machinery price has a significant effect upon demand but it has an effect in the opposite direction from what a complement is expected to have. In model (6.52) the machinery price has a negative effect as expected. The elasticity of fuel and oil demand with respect to last year's machinery price is estimated to be 0.14 in model (6.50) and -0.14 in model (6.52) (Table 6.6). Thus, fuel and oil demand is expected to change very little as machinery prices change relative to the prices received by farmers.

Stable models of fuel and oil demand have lower mean square errors if average acreage per farm is used versus total crop acreage. In model (6.43) the demand elasticity with respect to acreage per farm is estimated to be 0.3; in model (6.45) the estimate is 1.4. The demand for fuel and oil is very elastic with respect

Table 6.6. Estimated elasticities of demand for fuel and oil with respect to prices and other variables, selected models[a]

Model	$\frac{P_{fo}}{P_{Rt}}$	$\frac{P_{fo}}{P_{Ht}}$	$\frac{P_{fo}}{P_{Ht-1}}$	$\frac{P_e}{P_{Rt}}$	$\frac{P_H}{P_{Rt}}$	$\frac{P_M}{P_{Rt}}$	$\frac{P_M}{P_{Rt-1}}$
6.43	.19				-.08		
	(.06)				(.06)		
6.44	-.74				-.71	1.39	
	(.54)				(.47)	(.55)	
6.45		.62	.40				
		(.50)	(.27)				
6.47		-.94					
		(.66)					
6.48		-.29					
		(.13)					
6.50							.14
							(.08)
6.51[b]	.14			.18	-.17		
	(.06)			(.07)	(.07)		
6.52[b]							-.14
							(.08)

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

A'_t	TA_t	Y_{AFt-1}	V_{t-1}	S_{Mt}
.33		.18	.009	
(.26)		(.06)	(.007)	
			.019	.22
			(.007)	(.10)
1.37		.56	-.040	.18
(1.09)		(.22)	(.020)	(.11)
	13.11	.52		
	(4.74)	(.20)		
	6.51	.34		
	(0.86)	(.06)		
		.12	.006	.05
		(.04)	(.005)	(.04)
	6.43			
	(1.12)			

to total acreage. These elasticity estimates range from 6.4 to 13.1; thus, a one percent rise in total acreage is estimated to increase fuel and oil demand by six to thirteen percent with all other variables held constant.

Net farm income is estimated to have a positive, although inelastic, effect upon fuel and oil demand. Excluding some models due to unstable coefficients and wrong signs, a ten percent rise in net farm income is estimated to cause a three to five percent rise in fuel and oil demand. The effect of variation in net farm income is ambiguous from the results in Table 6.6; its coefficient is often insignificant in other models not reported.

The stock of farm machinery is estimated to have a significant, positive effect upon fuel and oil demand. The reaction is inelastic; the demand elasticity with respect to machinery stock is expected to range from 0.1 to 0.2 in the models reported.

Slowly changing variables exert a positive influence upon fuel and oil demand. In models (6.43) and (6.44) the coefficient on the time variable is negative but very unstable. The inclusion of the lagged expenditures on fuel and oil gives no significant results or caused other variables to have insignificant effects.

For the years the data cover, expenditures appear to be a function of the total acreage covered and the slowly changing variables such as new technologies and the adoption of new technologies and practices. The prices of fuel and oil and other inputs have had little effect upon demand. As the fuel price rises more and as the adoption of new technologies and practices becomes wider spread, the national expenditure level may respond to prices in a significant manner.

In many ways electricity is similar in its history to fuel and oil. The level of usage has increased as the adoption and ability to adopt new technologies and practices has spread across the U.S. The results of the electricity analysis are presented next.

Electricity

Expenditures for electricity includes all purchases of electricity for farm work. Only electricity used in the farm business is counted; no home use is included.

Electrical demand is hypothesized to be a function of the prices of electricity and fuel and oil, the farm wage rate, the prices received by farmers, the size and number of farms, the ratio of farmers' equity to outstanding debt, net farm income, the variation between expected and actual net farm income, and slowly changing variables accounted for in the time variable. Various models are formulated from these variables to test hypotheses and to estimate the quantitative effects of these variables upon the demand for electricity.

Farmers' demand for electricity is interpreted differently when the model is estimated using the data in original form than when the model is estimated using the data in logarithmic form. Models (6.53), (6.54), and (6.55) are estimated using the data in original form (Table 6.7). Models (6.56), (6.57), and (6.58) are estimated using the data in logarithmic form.

Excluding the lagged expenditures when using the data in original form causes very unstable coefficient estimates and theoretically wrong signs on the price variable coefficients. When the lagged expenditures variable is added these problems are corrected and the mean square error improves by a factor of ten. The estimated coefficients on the lagged variable is greater than one. If this were an adjustment model, the adjustment coefficient would be negative causing the long-run coefficients to reverse signs; the idea of electrical demand moving directly with electricity price changes causes the adjustment model to be bypassed in favor of another model.

The models of electrical demand using the data in original form fit the expectation model as formulated in Chapter II. In that formulation (Model I) farmers behave according to expected income; the coefficients estimated are short-run coefficients except for the price coefficients which are long-range. The expectation coefficient estimate will not alter the sign of the price coefficient

Table 6.7. Estimates of structural coefficients of demand for electricity[a]

Model	s^2	$\hat{R}^{2b}$	Intercept	$\frac{P_e}{P_{Rt}}$	$\frac{P_H}{P_{Rt}}$	$\frac{P_{fo}}{P_{Rt}}$
6.53	63.5	1.000	568	-90	128	
			(195)	(24)	(30)	
6.54	60.5	1.000	561	-90	129	
			(166)	(23)	(29)	
6.55	83.6	1.000	400	-93	99	
			(417)	(51)	(47)	
6.56[c]	.0083	1.000	3.02	-.89	.38	1.31
			(1.00)	(.29)	(.35)	(25)
6.57[c]	.0082	1.000	2.04	-.73		1.43
			(.46)	(.25)		(.23)
6.58[c]	.0068	1.000	2.04	-.80		1.24
			(.60)	(.29)		(.44)

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or Appendix A for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

A'_t	E_t	Y_{AFt-1}	V_{t-1}	T	Q_{et-1}	ρ
.03		-.004	.0000016	-9	1.2	-.41
(.28)		(.001)	(.0000004)	(4)	(0.1)	(.24)
		-.004	.0000016	-9	1.2	-.42
		(.001)	(.0000003)	(3)	(0.1)	(.23)
	-2.6		.0000008	-6	1.1	-.11
	(6.0)		(.0000003)	(6)	(0.3)	(.34)
				.04		.35
				(.01)		(.17)
				.05		.31
				(.01)		(.17)
				.04	.13	.20
				(.01)	(.25)	(.25)

estimates but it will reverse the signs on the other variables. Hence, the short-run, negative responses due to net farm income and the slowly changing variables become positive in the long-run and the price coefficients remain as estimated.

When the data are transformed logarithmically the models fit neither the expectation nor the adjustment model formulations. The lagged expenditures variable does not exert a significant influence on demand in model (6.58). The price of fuel and oil exerts a significant influence upon demand for electricity when the models are estimated using logarithmic data but not when using the data in original form.

There are differences in the elasticity estimates depending upon the type of data transformation used. The elasticity of demand with respect to the price of electricity is estimated to be about -0.5 using original forms and -0.7 to -0.9 using logarithmic forms (Table 6.8). Thus, a ten percent rise in electricity prices is estimated to cause a five to nine percent fall in the demand for electricity. The elasticity of demand with respect to the farm wage rate is estimated to range from 0.4 to 0.5; an electrical demand increase of four to five percent can be expected if farm wage rates rise by ten percent.

The demand for electricity is quite elastic with respect to the price of fuel and oil. These are more direct substitutes so

Table 6.8. Estimated elasticities of demand for electricity with respect to prices and other variables, selected models[a]

Calculated from model:	$\frac{P_e}{P_{Rt}}$	$\frac{P_H}{P_{Rt}}$	$\frac{P_{fo}}{P_{Rt}}$	A'_t	E_t	Y_{AFt-1}	V_{t-1}
6.53[b]	-.47	.50		.04		-.31	.06
	(.13)	(.12)		(.41)		(.11)	(.01)
6.54[b]	-.47	.50				-.31	.06
	(.12)	(.11)				(.11)	(.01)
6.55[b]	-.48	.39			-.09		.03
	(.27)	(.18)			(.22)		(.01)
6.56[c]	-.89	.38	1.31				
	(.29)	(.35)	(.25)				
6.57[c]	-.73		1.43				
	(.25)		(.23)				

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

[c]Long-run estimates for the adjustment or expectation model can be estimated by using the coefficient on the lagged dependent variable.

a ten percent rise in the price of fuel and oil is estimated to cause a thirteen to fourteen percent rise in the demand for electricity in the long-run with all other factors constant.

In models (6.53), (6.54), and (6.55) the elasticity of electrical demand with respect to prices received by farmers for all products is estimated to be 0.03 to 0.11 which is quite inelastic. In model (6.57) this elasticity is estimated to be -0.7 which is fairly elastic but it has a theoretically wrong directional effect.

Acres per farm and the farmers' equity ratio have no significant effect on demand for electricity. This is true whether the data are in original or logarithmic form.

Net farm income has a significant effect using the data in original form but not in logarithmic form. In models (6.53) and (6.54) the long-range elasticity of electrical demand with respect to net farm income is estimated to be 1.55 which is fairly elastic. A ten percent rise in net farm income is estimated to increase the demand for electricity by fifteen and a half percent in the long-run with all other factors constant. The long-run demand elasticity with respect to variation in net farm income is estimated to be -0.2 to -0.3 which is inelastic but significant.

After analyzing the general inputs of fuel and oil and electricity, the analysis of more product specific inputs is presented. First, seed demand is analyzed and then fertilizer and lime, pesticides, and feed.

Seed

Farmers' expenditures for seed include only seed for crop production. These crops include row crops, small grain crops, vegetable and fruit crops, legume and nonlegume meadow crops and other agricultural crops. The seed is for farm use and production only.

Seed demand is hypothesized to be a function of the prices of seed, fertilizer and lime, and pesticides relative to the prices received for crops; the number and size of farms; the ratio of farmers' equity to outstanding debt, national net farm income, the variation between expected and actual net farm income, and slowly changing variables accounted for in a time variable. These variables are combined in various groupings to test hypotheses and estimate the quantitative effects of changes in explanatory variables upon the demand for seed.

Specified by itself, the price of seed has a significant and opposite effect on the demand for seed (Table 6.9). Apparently, seed, fertilizer and lime, and pesticides prices are correlated enough to cause undesirable effects on the sign of the price of seed as in models (6.59) and (6.60). In models (6.63) and (6.64) the short-run elasticity of demand with respect to seed price is estimated to be -0.45 and -0.44, respectively, by assuming an adjustment model (Table 6.10). These two long-run estimates fit well with the long-run estimate of -0.43 in model (6.62) thus

Table 6.9. Estimates of structural coefficients of demand for seed[a]

Model	s^2	$\hat{R}^{2b}$	Intercept	$\frac{P_s}{P_{CRPt}}$	$\frac{P_{fr}}{P_{CRPt}}$	$\frac{P_c}{P_{CRPt}}$
6.59	1,954	.997	307	535	-350	-152
			(591)	(213)	(185)	(184)
6.60	1,847	.995	187	542	-467	
			(384)	(179)	(152)	
6.61	712	.999	-2,390	-199		
			(752)	(99)		
6.62	631	.998	-3,648	-308		
			(647)	(120)		
6.63	748	.999	-1,117	-169		
			(244)	(107)		
6.64[d]	.00156	1.000	2.44	-.10		
			(1.37)	(.11)		
6.65[d]	.00179	1.000	2.69	-.10		
			(.86)	(.20)		
6.66[d]	.00162	1.000	2.02			
			(1.30)			

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or appendix for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]Autocorrelation is insignificant so the model is reestimated with no such coefficient.

[d]The equation is estimated with the data in logarithmic form except time.

N_t	A'_t	E_t	Y_{AFt-1}	V_{t-1}	T	Q_{st-1}	ρ
	.69	-7.6		.000002	2.8		.10
	(2.60)	(22.1)		(.000001)	(19.3)		(.23)
	1.4		-.003	.000003			.30
	(0.8)		(0.12)	(.000002)			(.27)
.15			.015	-.000003	38	.24	.22
(.07)			(.006)	(.000001)	(11)	(.23)	(.33)
.27			.010	-.000003	56		.64
(.07)			(.006)	(.000001)	(8)		(.20)
	-1.7		.019	-.000004	31	.47	-[c]
	(1.1)		(.005)	(.000001)	(9)	(.15)	
	-.33				.016	.76	-.25
	(.21)				(.008)	(.13)	(.19)
			.21		.029		.70
			(.08)		(.003)		(.12)
	-.23				.012	.78	-.34
	(.19)				(.007)	(.12)	(.18)

Table 6.10. Estimated elasticities of demand for seed with respect to prices and other variables, selected models[a]

Calculated from model:	$\frac{P_S}{P_{CRPt}}$	N_t	A'_t	Y_{AFt-1}	V_{t-1}
6.62	-.43	1.54		.24	-.03
	(.17)	(.42)		(.16)	(.01)
6.63[b]	-.24		-.76	.45	-.04
	(.15)		(.50)	(.12)	(.01)
6.64[b,c]	-.10		-.33		
	(.11)		(.21)		
6.66[b,c]			-.23		
			(.19)		

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Long-run estimates for the adjustment or expectation model can be estimated by using the coefficient on the lagged dependent variable.

[c]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

reinforcing the assumption of the adjustment model. A ten percent rise in seed prices with all other variables held constant is estimated to create a one to two percent fall in seed demand in the short-run and a four to a four and one-half percent fall in demand in the long-run. Seed demand is thus fairly inelastic in response to seed price changes.

Since the seed price enters the model as a ratio with the prices received for crops by farmers, effects of the same magnitude but opposite direction are estimated. The elasticity of seed demand with respect to prices received for crops is estimated to be 0.1 to 0.2 in the short-run and 0.43 to 0.45 in the long-run. A ten percent rise in crop prices is estimated to cause a four to four and one-half percent rise on seed demand in the long-run with all other factors constant. The demand for seed is inelastic in response to crop price changes. The equal but reverse response to seed price is due to the restrictions placed on the model.

Since Heady and Tweeten (1963) analyzed seed demand, the price of seed has become a significant factor in the demand for seed. In their analysis Heady and Tweeten found both seed price and prices received to have no significant effect upon seed demand. The inelastic but significant effect estimated in this analysis is expected since the data are from recent years when a larger proportion of seed is purchased rather than produced on the farm.

The demand for seed is estimated to have an elastic response to changes in the number of farms and to acres per farm in the long-run. A ten percent decline in the number of farms is estimated to cause a fifteen percent decrease in seed demand. A ten percent rise in the average acreage per farm is estimated to cause a ten to fourteen and one-half percent fall in the demand for seed. These estimates assume that all other conditions are stable.

The estimate of demand response to changes in net farm income varies with the model formulated. In all cases the effect is direct, significant, and inelastic. In model (6.62) the demand elasticity is estimated to be 0.2; in model (6.63) the elasticity is estimated to be 0.45 in the short-run and 0.8 in the long-run. The variation in net farm income has a very inelastic but opposite effect upon seed demand. A ten percent increase in net income variation is estimated to cause less than a one percent decline in seed demand in the long-run.

Seed is the start of all crop production. Fertilizer and lime which help the seed grow are analyzed next.

Fertilizer and lime

Fertilizer and lime contribute to the productivity of the soil and are complements of each other so they are grouped together in this analysis. Only farmers' expenditures for fertilizer and lime for use in crop production are counted. These crops include row crops, small grain crops, vegetable and fruit crops, legume and nonlegume meadow crops, and other agricultural crops.

The demand for fertilizer and lime is described as a function of its own price and the prices of seed and pesticides relative to the prices received for crops, the number and size of farms, the ratio of farmers' equity to outstanding debt, national net farm income, the variation between expected and actual net farm income, and other, slowly changing variables accounted for by the time variable. These variables are used to develop several models to test hypotheses and estimate the quantitative effects of changes in explanatory variables upon the demand for fertilizer and lime.

The response of fertilizer and lime demand to changes in its own price is estimated to be opposite in direction (Table 6.11). Using the data in the original form the response is estimated to be elastic; using logarithmic data the response is estimated to be inelastic (Table 6.12). Using the original data the elasticity of demand with respect to its own price is estimated to range from -1.0 in model (6.68) to -1.5 in model (6.71). With logarithmically transformed data the demand elasticity is estimated to be -0.4 in the short-run and -0.56 in the long-run using model (6.77) as an adjustment model and -0.55 in the long-run in model (6.74). The elastic responses may be true for past years as fertilizer prices dropped relative to crop prices and more and more farmers

Table 6.11. Estimates of structural coefficients of demand for fertilizer and lime[a]

Model	s^2	$\hat{R}^{2b}$	Intercept	$\frac{P_{fr}}{P_{CRPt}}$	$\frac{P_s}{P_{CRPt}}$
6.67	11,987	.996	2,180	-2,433	1,567
			(2,122)	(770)	(756)
6.68	9,143	.997	-994	-2,042	903
			(895)	(287)	(334)
6.69	13,712	.992	2,624	-3,381	1,978
			(2,269)	(956)	(851)
6.70	13,002	.996	2,062	-2,736	1,800
			(2,193)	(545)	(668)
6.71	15,120	.996	6,361	-3,039	2,225
			(6,403)	(647)	(995)
6.72	12,092	.996	1,887	-2,611	1,826
			(1,291)	(344)	(405)
6.73	10,053	.997	963	-1,884	927
			(5,867)	(1,260)	(1,105)
6.74[c]	.0019	1.000	6.23	-.55	.36
			(1.05)	(.10)	(.14)
6.75[c]	.0019	1.000	4.70	-.57	.23
			(0.83)	(.14)	(.15)
6.76[c]	.0023	1.000	2.96	-.66	.61
			(4.47)	(.13)	(.23)
6.77[c]	.0017	1.000	5.61	-.40	.36
			(1.17)	(.12)	(.13)

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or appendix for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

Table 6.11. Estimates of structural coefficients of demand for fertilizer and lime[a]

Model	s^2	$\hat{R}^{2b}$	Intercept	$\frac{P_{fr}}{P_{CRPt}}$	$\frac{P_s}{P_{CRPt}}$
6.67	11,987	.996	2,180	-2,433	1,567
			(2,122)	(770)	(756)
6.68	9,143	.997	-994	-2,042	903
			(895)	(287)	(334)
6.69	13,712	.992	2,624	-3,381	1,978
			(2,269)	(956)	(851)
6.70	13,002	.996	2,062	-2,736	1,800
			(2,193)	(545)	(668)
6.71	15,120	.996	6,361	-3,039	2,225
			(6,403)	(647)	(995)
6.72	12,092	.996	1,887	-2,611	1,826
			(1,291)	(344)	(405)
6.73	10,053	.997	963	-1,884	927
			(5,867)	(1,260)	(1,105)
6.74[c]	.0019	1.000	6.23	-.55	.36
			(1.05)	(.10)	(.14)
6.75[c]	.0019	1.000	4.70	-.57	.23
			(0.83)	(.14)	(.15)
6.76[c]	.0023	1.000	2.96	-.66	.61
			(4.47)	(.13)	(.23)
6.77[c]	.0017	1.000	5.61	-.40	.36
			(1.17)	(.12)	(.13)

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or appendix for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

$\frac{P_c}{P_{CRPt}}$	$\frac{P_{fr}}{P_{CRPt-1}}$	N_t	A'_t	E_t	Y_{AFt-1}	V_{t-1}
-316				-173	.009	.00001
(434)				(60)	(.030)	(.00001)
				-114	.04	
				(40)	(.01)	
				-181	-.01	.00002
				(61)	(.04)	(.00001)
				-149	-.01	.000001
				(53)	(.03)	(.000001)
		-.43		-134		.000015
		(.56)		(56)		(.000007)
			5.9	-127		.000013
			(6.1)	(52)		(.000004)
		.06		-126		.000008
		(.47)		(62)		(.000012)
				-.83	.12	.023
				(.13)	(.11)	(.013)
	-.01			-.73	.25	
	(.10)			(.14)	(.09)	
			.88	-.65		.043
			(.91)	(.20)		(.014)
				-.67		.026
				(.14)		(.009)

Table 6.11. Continued

Model	T	Q_{frt-1}	ρ
6.67	30	.31	.46
	(24)	(.25)	(.35)
6.68	65		.37
	(11)		(.22)
6.69	35	-.21	.95
	(26)	(.28)	(.46)
6.70	28		.33
	(27)		(.17)
6.71	-21		.26
	(76)		(.30)
6.72	-6		.36
	(44)		(.28)
6.73	30	.27	.09
	(53)	(.36)	(.45)
6.74[c]	.021		.16
	(.005)		(.21)
6.75[c]	.028		.49
	(.005)		(.25)
6.76[c]	.001		.08
	(.020)		(.26)
6.77[c]	.011	.278	-.01
	(.006)	(.173)	(.29)

Table 6.12. Estimated elasticities of demand for fertilizer and lime with respect to prices and other variables, selected models[a]

Calculated from model:	$\frac{P_{fr}}{P_{CRPt}}$	$\frac{P_s}{P_{CRPt}}$	$\frac{P_c}{P_{CRPt}}$	N_t	A'_t	E_t	Y_{AFt-1}	V_{t-1}
6.67	-1.18	.82	-.17			.70	.08	.04
	(.37)	(.39)	(.23)			(.24)	(.26)	(.03)
6.68	-.99	.47				-.46	.36	
	(.14)	(.17)				(.16)	(.09)	
6.70	-1.33	.94				-.60	-.08	.05
	(.26)	(.35)				(.21)	(.30)	(.03)
6.71	-1.48	1.16		.93		-.54		.06
	(.31)	(.52)		(1.20)		(.22)		(.03)
6.72	-1.27	.95			.96	-.51		.05
	(.17)	(.21)			(1.00)	(.21)		(.02)
6.74[b]	-.55	.36				-.83	.12	.02
	(.10)	(.14)				(.13)	(.11)	(.01)
6.77[b,c]	-.40	.36				-.67		.03
	(.12)	(.13)				(.14)		(.01)

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

[c]Long-run estimates for the adjustment or expectation model can be estimated by using the coefficient on the lagged dependent variable.

adopted fertilizing practices. But the inelastic responses may be more accurate as the adoption process nears completion and national levels reflect a full or nearly full adoption of fertilizing practices.

In all these models the seed price coefficient is estimated to be positive indicating that seed and fertilizer and lime are substitutes. Again there is a difference in estimates between the original data and logarithmically transformed data; the same reasons hold for accepting the two ranges. Using the original data the elasticity of demand with respect to the price of seed is estimated to range from 0.5 to 1.2; using transformed data, from 0.4 to 0.5 in the long-run. The elastic responses may be affected by unstable coefficients so the response is estimated to be inelastic.

The demand elasticity with respect to crop prices is positive but quite low. It is estimated to be 0.1 in model (6.77) and up to 0.5 in model (6.68). A ten percent fall in crop prices is estimated to cause a one to five percent fall in the demand for fertilizer and lime.

In their study Heady and Tweeten (1963) estimate the elasticity of fertilizer and lime demand with respect to its own price to be -0.5 and with respect to prices received, 0.5. Their estimates are very close to the estimates in this study using logarithmic transformations but are less than those using original data. This study estimates the response in fertilizer and lime demand to be more inelastic with respect to crop prices than Heady and Tweeten's estimate with respect to all prices received.

The number and size of farms do not have significant effects upon fertilizer and lime demand.

The demand for fertilizer and lime responds negatively to changes in the farmers' equity ratio. This gives support to the hypothesis that farmers will increase their use of operating inputs as their debts increase relative to equity. If a farmer buys more land or new machinery, this negative coefficient indicates that the demand for fertilizer and lime increases to increase production, and thus returns to the additional land or machinery. The estimates of the elasticity of demand with respect to the equity ratio range from -0.45 to -0.85; thus with a ten percent decrease in the equity ratio, demand is estimated to rise by four and a half to eight and a half percent.

The impact of net farm income is insignificant in some models but not all models. When the coefficients are significant the elasticity is estimated to be 0.36. Thus, if income does change, demand for fertilizer and lime responds inelastically if it does respond at all. The variation in net farm income has a positive impact upon fertilizer and lime demand but is not significant in all models. Demand response to changes in net farm income variation is estimated to be quite inelastic whether the coefficient is significant or not.

When the coefficient is stable, slowly changing variables do have a positive and significant effect upon fertilizer and lime demand as shown in the coefficients on the time variable. Thus, psychological, institutional, and other factors are apparently changing to increase the demand for fertilizer and lime.

Only in model (6.77) do the lagged expenditures have a significant coefficient. In several other models this variable is insignificant. Evidently, demand for fertilizer and lime is flexible as are most of the operating inputs.

After analyzing farmers' demand for seed and fertilizer and lime it is fitting to analyze the demand for pesticides which decrease competition for the economic crop. The results of that analysis are next.

Pesticides

Pesticides are herbicides, insecticides, fungicides, and other chemicals used in the soil or plants to minimize the effects of weeds, crop predators, and plant diseases. Only farmers' expenditures for pesticides applied in crop production are used in this study. The crops included are row crops, small grain crops, vegetable and fruit crops, legume and nonlegume meadow crops, and other agricultural crops.

The demand for pesticides is hypothesized to be a function of its own price and the prices of fertilizer and lime and seed relative to the crop prices received by farmers; the size of farms; the ratio of farmers' equity to outstanding debt, national net farm income, the variation between expected and actual net farm income, and other, slowly changing variables represented by the time variable. These variables are used to develop several models to test hypotheses and estimate the quantitative effects of changes in explanatory variables on the demand for fertilizer and lime.

Once again the correlation between the prices of seed, fertilizer and lime, and pesticides causes problems of instability and theoretically wrong signs on the pesticide price coefficients. When specified as the only price, the pesticide price is estimated to have a significant negative effect on pesticide demand (Table 6.13). The lagged pesticide price is estimated to have a positive effect and is dropped from further analysis. The demand for pesticides with respect to its own price is estimated to be elastic; it ranges from -1.1 in model (6.84) to -1.6 in model (6.83). (Table 6.14). A ten percent rise in pesticide prices is estimated to lower pesticide demand by eleven to sixteen percent.

Several models have unstable coefficient estimates and are excluded from further analysis. The models using logarithmic data proved hard to formulate to give stable estimates of all coefficients.

The effect of average farm size is difficult to discern. In several models the coefficient estimates are unstable; when the estimates are stable, the estimate is positive in some models and negative in others. The demand for pesticides is estimated to be

Table 6.13. Estimates of structural coefficients of demand for pesticides[a]

Model	s^2	$\hat{R}^{2b}$	Intercept	$\frac{P_c}{P_{CRPt}}$	$\frac{P_c}{P_{CRPt-1}}$
6.78	2,127	.997	-45 (488)	219 (175)	
6.79	7,619	.981	2,604 (1,869)	-130 (409)	
6.80	8,530	.978	-1,494 (903)	109 (352)	
6.81	6,635	.977	-2,175 (775)	-748 (260)	
6.82	8,012	.967	-2,042 (830)	-800 (284)	310 (228)
6.83	8,578	.964	-2,234 (787)	-844 (295)	
6.84	5,983	.968	-4,656 (1,595)	-575 (234)	
6.85[c]	.015	1.000	6.0 (2.1)	-.35 (.57)	-.47 (.42)
6.86[c]	.013	1.000	16.5 (5.1)	-.09 (.23)	

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or appendix for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

$\frac{P_{fr}}{P_{CRPt}}$	$\frac{P_s}{P_{CRPt}}$	N_t	A'_t	E_t	Y_{AFt-1}	V_{t-1}
-717	375			-26		
(158)	(188)			(14)		
-1,894	1,811		4.4	-73	-.03	.00001
(508)	(597)		(4.4)	(41)	(.03)	(.00001)
-1,345			-5.6	-20		
(323)			(3.4)	(37)		
			-4.3		.02	-.000005
			(5.5)		(.02)	(.000003)
			7.5		.05	-.000005
			(1.2)		(.02)	(.000004)
					.04	-.000008
					(.02)	(.000004)
		.39		-34		-.000002
		(.16)		(35)		(.000002)
1.08				-1.3		
(.47)				(.4)		
			-2.4	-1.59		
			(0.9)	(.41)		

Table 6.13. Continued

Model	T	Q_{ct-1}	ρ
6.78	8	.66	-.09
	(7)	(.12)	(.20)
6.79	-39		.29
	(41)		(.31)
6.80	81		.23
	(19)		(.26)
6.81	72		.45
	(35)		(.16)
6.82			.59
			(.14)
6.83	48		.56
	(7)		(.19)
6.84	72		.81
	(16)		(.20)
6.85[c]	.018	.23	.09
	(.022)	(.21)	(.24)
6.86[c]	.06	.47	-.13
	(.02)	(.16)	(.19)

Table 6.14. Estimated elasticities of demand for pesticides with respect to prices and other variables, selected models[a]

Calculated from model:	$\frac{P_c}{P_{CRPt}}$	$\frac{P_{fr}}{P_{CRPt}}$	$\frac{P_s}{P_{CRPt}}$	N_t	A'_t	E_t	Y_{AFt-1}	V_{t-1}
6.79	-.24 (.77)	-3.29 (.88)	3.37 (1.11)		2.55 (2.59)	-1.05 (.58)	-.95 (.90)	.18 (.11)
6.81	-1.41 (.49)				-2.50 (3.23)		.64 (.60)	-.07 (.06)
6.83	-1.59 (.56)						1.26 (.48)	-.11 (.05)
6.84	-1.08 (.44)			2.97 (1.24)		-.49 (.50)		-.02 (.03)

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

very elastic with respect to the number of farms in model (6.84) but this may be wrong due to two unstable estimates in the same model. Hence, the number and size of farms do not have a large impact on pesticide demand.

The equity ratio also appears to have no significant effect upon pesticide demand. The coefficient estimate is consistently negative but is insignificant or may be affected by other insignificant variables.

Pesticide demand does increase as national net farm income increases. It is not always significant but when other variables in the model have stable coefficient estimates net farm income has a stable, positive effect. In model (6.83) in which all variables have stable coefficient estimates, the elasticity of pesticide demand with respect to net farm income is estimated to be 1.3. From this a ten percent rise in net farm income is estimated to raise pesticide demand by thirteen percent. The variation in net farm income is estimated to have significant negative inelastic effects upon pesticide demand.

When the effect is significant, slowly changing variables increase the demand for pesticides. The lagged pesticide expenditures produced theoretically wrong signs on the price variable and were thus dropped from further analysis.

Pesticides are the final specific crop input to be analyzed. The results of the analysis of feed demand are presented next.

Feed

Farmers' expenditures for feed includes feed for beef cattle, swine, sheep, dairy cattle, and poultry for slaughter, replacement, and breeding. Feed for horses and mules doing farm work is included also.

The demand for feed is hypothesized to be a function of its own price. The number and size of farms, the ratio of farmers' equity to outstanding debt, the national personal disposable income, the national net farm income, the variation between expected and actual net farm income, and other, slowly changing variables accounted for by the time variable. These variables are combined into several models of feed demand to test hypotheses and estimate the quantitative effects of changes in explanatory variables.

Changes in the price of feed cause changes in the opposite direction in demand for feed (Table 6.15). These responses are inelastic in the short-run and near unity in the intermediate term (Table 6.16). Excluding those models with unstable coefficients the short-range elasticity is estimated to range between -0.35 and -0.7 and the intermediate-range elasticity ranges between -0.6 and -1.0. A ten percent rise in feed prices with all other factors constant is estimated to cause a three and one half to seven percent reduction in feed demand in the short range and a six to ten percent reduction in the intermediate range. In model (6.89) the long-range elasticity is estimated to be -0.9, that is, a ten

Table 6.15. Estimates of structural coefficients of demand for feed[a]

Model	s^2	$\hat{R}^{2b}$	Intercept	$\frac{P_{fd}}{P_{LKt}}$	$\frac{P_{fd}}{P_{LKt-1}}$
6.87	46,319	.997	9,653 (5,321)	-2,630 (1,014)	-2,711 (510)
6.88	32,765	.999	16,105 (3,783)	-2,281 (707)	-2,096 (482)
6.89	64,215	.999	12,726 (4,651)	-3,632 (697)	
6.90	33,737	.999	1,342 (1,794)	-2,207 (708)	-1,550 (530)
6.91	69,976	.996	21,866 (9,135)	-3,717 (1,405)	-1,891 (727)
6.92[c]	.00069	1.000	25 (3)	-.31 (.12)	-.31 (.09)
6.93[c]	.00081	1.000	25 (4)	-.36 (.13)	-.27 (.09)
6.94[c]	.00220	1.000	28 (7)	-.71 (.17)	

[a]Unless noted, estimates are made as single equations within a system using MLIML estimators with $\alpha = 1$, data in original form, and corrected for autocorrelation. See text or appendix for explanation of variable names.

[b]The $\hat{R}^2$ statistic is a rough measure calculated outside of the estimation program. The estimated error sum of squares is divided by the corrected sum of squares of the transformed dependent variable.

[c]The equation is estimated with the data in logarithmic form except time.

N_t	A'_t	E_t	Y_{Dt}	Y_{AFt-1}	V_{t-1}
-1.2		156		.04	-.000003
(0.6)		(89)		(.06)	(.000011)
-1.5		189	.008		
(0.4)		(75)	(.002)		
-1.1		150	.006		
(0.4)		(100)	(.003)		
	31	162	.003		
	(7)	(67)	(.002)		
-1.4			.008		.00001
(0.6)			(.004)		(.00001)
-2.1		.42		.06	-.014
(0.3)		(.10)		(.07)	(.007)
-2.1		.41	.14		
(0.3)		(.11)	(.19)		
-2.3		.48	.07		
(0.6)		(.19)	(.30)		

Table 6.15. Continued

Model	T	Q_{fdt-1}	ρ
6.87	68		.63
	(54)		(.13)
6.88	-87		.30
	(62)		(.22)
6.89	-65	.25	-[d]
	(74)	(.14)	
6.90	-69		-[d]
	(49)		
6.91	-147		.52
	(121)		(.29)
6.92[c]	-.013		.00
	(.007)		(.18)
6.93[c]	-.021		.02
	(.008)		(.20)
6.94[c]	-.019	-.07	.18
	(.011)	(.21)	(.33)

[d]Autocorrelation is insignificant so the model is reestimated with no such coefficient.

Table 6.16. Estimated elasticities of demand for feed with respect to prices and other variables, selected models[a]

Calculated from model:	$\frac{P_{fd}}{P_{LKt}}$	$\frac{P_{fd}}{P_{LKt-1}}$	N_t	A'_t	E_t	Y_{Dt}	Y_{AFt-1}	V_{t-1}
6.87	-.49 (.19)	-.51 (.10)	-.86 (.44)		.21 (.12)		.11 (.17)	-.003 (.015)
6.88	-.43 (.13)	-.39 (.09)	-1.07 (.26)		.26 (.10)	.66 (.20)		
6.89[b]	-.68 (.13)		-.84 (.33)		.21 (.14)	.47 (.27)		
6.90	-.41 (.13)	-.29 (.10)		1.8 (0.4)	.22 (.09)	.26 (.15)		
6.91	-.70 (.26)	-.35 (.14)	-1.03 (.47)			.70 (.30)		.02 (.01)
6.92[c]	-.31 (.12)	-.31 (.09)	-2.1 (0.3)		.42 (.10)		.06 (.07)	-.014 (.007)
6.93[c]	-.36 (.13)	-.27 (.09)	-2.1 (0.3)		.41 (.11)	.14 (.19)		

[a]Elasticities are calculated using variable averages except for estimates from logarithmic data. Models are selected on the basis of coefficient stability and model acceptability.

[b]Long-run estimates for the adjustment or expectation model can be estimated by using the coefficient on the lagged dependent variable.

[c]Data are in logarithmic form. The elasticities are estimated directly as coefficient estimates.

percent rise in feed price is estimated to cause a nine percent decrease in the demand for feed.

Since the ratio of feed price to prices received for livestock is used, it is assumed that the two prices have proportionally equal but opposite effects upon feed demand. A ten percent rise in livestock prices relative to the feed price is estimated to cause a three and a half percent rise in feed demand in the short-range, six to ten percent rise in the intermediate range, and nine percent in the long-range if all other variables are constant.

Heady and Tweeten's (1963) estimate of the short-run feed demand elasticity with respect to feed price is -1.0. This is greater than the -0.35 to -0.7 estimated in this study. Even the long-range estimate is less elastic than their estimate. The estimate of the demand elasticity with respect to livestock prices is also less than the estimate by Heady and Tweeten. The U.S. demand for meat may have grown more inelastic in recent years which would explain this decrease in elasticity of feed demand.

As the number of farms decreases and the size of farms increases, feed demand is estimated to increase. The demand response is estimated to be elastic with respect to changes in the number and size of farms. In model (6.89) the estimate of the short-range demand elasticity with respect to the number of farms is -0.84 and the long-range elasticity is estimated to be -1.13. The estimated elasticity with respect to farm numbers is -1.1 in model (6.88) and -2.1 in models (6.92) and (6.93). The feed demand elasticity with respect to farm size is estimated to be 1.8 in model (6.90). The response in feed demand to a ten percent reduction in the number of farms with all other factors constant is estimated to be an eleven to twenty-one percent increase in the long-range. If the average farm size increases by ten percent, the demand for feed is estimated to increase by eighteen percent provided no other variables change.

The demand for feed is the only operating input analyzed in this study that is estimated to have a direct but inelastic response to changes in the equity ratio. The coefficient on the equity ratio is positive and significant in all models of feed demand in this study whether the other variables are stable or not. The demand elasticity with respect to the equity ratio is estimated to be between 0.21 and 0.26 in the models using data in original form and about 0.41 in the models using logarithmically transformed data. Thus, with a ten percent increase in the equity ratio feed, demand is estimated to rise two to four percent.

In model (6.91) the equity ratio is excluded from the model specification. This causes no instability in the other coefficient estimates and the elasticity estimates fall in the ranges of other estimates. However, the mean square error does increase significantly suggesting the importance of the equity ratio in explaining feed demand.

The nickname of hogs as the "mortgage payers" may cast some doubt on the cause-effect relationship between the equity ratio and feed demand. Increasing profitability of livestock production may increase the demand for feed and improve the equity ratio as well. However, it is also common to hear of farmers abandoning livestock production for cash grain farming once they can afford to financially avoid the work associated with livestock. This latter example would indicate a negative coefficient on the equity ratio in models of feed demand. The former hypothesis is supported by results of this study.

The effect on feed demand of national personal disposable income is significant in those models using original data but is insignificant in models using logarithmically transformed data. In either set of models the response of feed demand with respect to disposable income is quite inelastic. It is estimated to be between 0.25 and 0.7 in models (6.88), (6.89) and (6.90).

The effect on the demand for feed of national net farm income is estimated to be insignificant with both original and logarithmically transformed data. The response in feed demand to changes in the variation between expected and actual income is very inelastic and significant only when using logarithmically transformed data.

Slowly changing variables represented in the time variable exhibit an effect that is not significant in every model of feed demand. Except in model (6.87) the coefficient is negative. When using logarithmically transformed data (except for the time variable) the effect of these slowly changing variables is significant.

Last year's expenditures for feed is estimated to have a significant effect on current expenditures in model (6.89) but not in all models using original data. When the data are logarithmically transformed as in model (6.94), the lagged expenditure is not significant. The improved mean square error without lagged expenditures indicates a model such as (6.1) is better fitting than an adjustment or expectation model.

The demand for feed is the last specific operating input to be analyzed. To end this chapter the results of the analysis presented is summarized.

Summary

Farmers' national demand for operating inputs is analyzed in this chapter. Operating inputs are those agricultural resources which are used up in one production period. Aggregate demand for all operating inputs and demand for specific inputs are analyzed by econometric methods to estimate quantitative effects and to test hypotheses of explanatory variable importance.

Since 1945 the level of farmers' expenditures for operating inputs has increased. Specific inputs have increased more rapidly than others but all operating inputs analyzed in this chapter have increased in use since 1945. The reasons for this change in use are analyzed in this chapter.

Prices and other explanatory variables are discussed; their potential impacts are hypothesized. Potential models of demand are presented and discussed. The basic system of equations for each input or input group is given; these basic systems are adopted as necessary for other demand models.

The parameters of the models are estimated using Fuller's modified limited information maximum likelihood estimator with $\alpha = 1$. Autocorrelation is corrected for as needed. The data used are from 1946 to 1977.

The demand for operating inputs in aggregate is analyzed first. From this aggregate measure several specific inputs are pulled out and analyzed separately. The specific inputs are fuel and oil, electricity, seed, fertilizer and lime, pesticides, and feed. The results of these analyses are summarized here.

The aggregate demand and all the individual demands except fuel and oil respond negatively and significantly to changes in their own prices. The prices received for crops and livestock exert a positive influence upon demand for all the operating inputs analyzed.

The elasticity of aggregate demand for operating inputs with respect to its own price is estimated to be near unity or greater. The demand elasticity is estimated to be between -1.1 and -1.5. A higher elasticity than Heady and Tweeten's (1963) estimate (-0.6) is expected since a larger proportion of inputs is purchased from nonfarm sources. The effect of the farm wage rate is difficult to determine; significant but inelastic responses are estimated with both direct and opposite responses.

The aggregate demand elasticity with respect to the average value of U.S. farmland is estimated to be about 0.5. Last year's machinery price is estimated to have a positive, inelastic effect upon aggregate demand; this elasticity is estimated to be between 0.2 and 0.4. Aggregate demand response to prices received is estimated to have an elasticity of 0.7 to 1.1.

Average farm size and the number of farms are estimated to have an inelastic effect on aggregate demand if any effect. Aggregate demand responds negatively and inelastically to changes in the equity ratio. The variation in net farm income has a significant opposite, although inelastic, effect upon aggregate demand. Using the original data, slowly changing variables have a positive effect. The lagged value of expenditures does not have a significant effect on aggregate demand.

Not very many models of fuel and oil demand estimate a negative reaction to the fuel and oil price. Those models which did are not acceptable for other reasons. The increase in total consumption has been great enough to overpower any adjustments by individual users to rising fuel and oil prices. The mean square error improves when the fuel and oil price is deleted from those models using original data. The demand for fuel and oil is inelastic to changes in last year's machinery price; this response is significant but the direction is difficult to evaluate from the models estimated.

Including average farm size in fuel and oil demand models results in lower mean square errors than including total crop acreage. Net farm income is estimated to have a positive, inelastic effect upon fuel and oil demand as is the stock of farm machinery. Slowly changing variables do have a positive effect upon demand. The lagged expenditure level does not have a significant effect or causes instability in other coefficients.

The demand for electricity is inelastic with respect to its own price; the elasticity is estimated to be from -0.5 to -0.9 depending upon the model specification. The elasticity of demand with respect to the farm wage rate is estimated to be fairly inelastic; it is quite elastic with respect to the price of fuel and oil. Prices received by farmers have a fairly inelastic effect upon electrical demand.

Net farm income has a significant, long-range elastic effect upon the demand for electricity using the original data but no significant effect when using logarithmic data. Income variation has a negative, inelastic effect.

The elasticity of seed demand with respect to its own price is estimated to be -0.45 in the long-run. There is a fairly inelastic demand for seed with respect to crop prices also. The demand for seed is estimated to have an elastic response to changes in the number of farms and acres per farm in the long-run. Net farm income influences seed demand in a direct but fairly inelastic manner. The effect of income variation is negative and very inelastic.

The demand for fertilizer and lime is estimated to be elastic and inelastic with respect to its own price depending on using the data in original or logarithmic form, respectively. The seed price is estimated to have an inelastic positive effect upon fertilizer and lime demand. Crop prices are estimated to have a positive but very inelastic effect upon demand. Changes in the equity ratio cause opposite and inelastic responses in fertilizer and lime demand. Net farm income is estimated to have a small positive effect as does income variation; these effects were not significant in all models. Fertilizer and lime demand is quite responsive to current prices and variables and the lagged expenditures is significant in only one model.

The demand for pesticides with respect to its own price is estimated to be -1.1 to -1.6; this is a fairly elastic response. Pesticide demand is also estimated to have positive unitary or greater elasticity with respect to net farm income. Income variation is estimated to have a negative but inelastic effect upon pesticide demand.

Feed demand is estimated to respond negatively to the feed price; the response being inelastic in the short-run and near unity in the intermediate-run. The price of livestock has a direct but inelastic effect upon feed demand. The feed demand response is estimated to be elastic with respect to changes in the number and size of farms; the response is opposite and direct for the number and size of farms, respectively.

The equity ratio has a significant, positive, and inelastic relationship with feed demand but the cause and effect relationship is hard to discern. National personal disposable income exerts a positive but quite inelastic influence upon feed demand. The mean square error improves when lagged feed expenditures is not included in a model specification; thus, feed demand is more responsive to current and last year's values than to a longer range view.

This finishes the analysis of operating input demand. The effects of prices and other variables have been estimated. In most situations the coefficient estimates were as expected but some differences were found. These results can be used to estimate the effect of changes in the explanatory variables upon the demand for aggregate or specific operating inputs.

CHAPTER VII. PREDICTIONS OF AGRICULTURAL RESOURCE USE IN 1990

The future structure and organization of agricultural resources in the U.S. is never known with certainty. Will the future consist of a few, very large farms using very capital intensive management practices? Will the future consist of many small farms using human labor and animal-power intensive practices? Or will the future lie somewhere inbetween these extremes? Or are there alternatives that we have not discovered or contemplated. These questions are never answered with certainty but people always are interested in attempts to answer them.

Many people close to agriculture are interested in what organization and structure agriculture will have in the future. While they are directly affected by and concerned about farm-level factors, farmers are interested in future changes and the potential effects upon their operations. Input suppliers need to make long-range plans for building plants and researching new ideas and practices. Rural communities are interested in what the future community needs will be as the number of farms and workers change. Product processors and handlers need to know whom they will be buying from: many, small operators needing local market facilities or few, large operations needing regional market facilities. Agricultural policy makers also need to know predictions of the future to help formulate policy for future needs.

In the first part of this study the structural coefficients of demand are estimated within a system for machinery and building and land improvements in Chapter IV, farm labor in Chapter V, and operating inputs in Chapter VI. These estimates show how responsive demand is to prices of the specific input and its substitutes and complements, to other variables, and to net farm income. These structural estimates are useful to estimate demand response to current conditions and variable changes and also can be used to estimate reduced form equations to predict resource organization in the future. However, reduced form equations calculated from structural equations may be adversely affected by specification errors in the structural equations.

To avoid prediction error due to specification error in the structural equations, the reduced form equations are estimated directly. The reduced form equations of the system

$$\beta Y_t + \Gamma X_t = u_t \tag{7.1}$$

are

$$Y_t = \pi X_t + V_t \tag{7.2}$$

where

$$\pi = -\beta^{-1}\Gamma$$

$$V_t = \beta^{-1}U_t$$

and β is a (GXG) matrix of coefficients of current endogenous variables, Γ is a (GXK) matrix of coefficients of predetermined variables, π is a (GXK) matrix of reduced form coefficients, and Y_t, X_t, u_t, and V_t are column vectors of G, K, G, and G elements of endogenous variables, predetermined variables, structural disturbances, and reduced form disturbances respectively. In this study the reduced form coefficients in (7.2) are estimated directly with data from 1946 to 1977 and are used to predict future agricultural resource organization.

By using the reduced form equations, effects of future changes in structural coefficients cannot be estimated explicitly. That is, the effect of an increasing price elasticity cannot be estimated by changing the structural coefficient and reestimating the reduced form coefficients. The assumption or prediction of increasing price elasticity would have a large error connected with it or would require an extensive analysis of farmers' tastes and preferences. For this study the error associated with such a prediction is too large to accept and an analysis of tastes and preferences is beyond the scope of this study. Thus, direct estimation of the reduced form coefficients is done in this study.

A problem with forecasting is the question of drastic changes in the future. It is one thing to estimate the effect of increasing fuel prices; it is something else to drastically reduce the supply of fuel or impose stringent soil loss controls, pesticide restrictions, and other environmental regulations. For these effects normative studies are needed; positive studies such as this one cannot cope with new occurrences unless assumptions are made about the unknown effect.

With the reduced form estimates two methods are used to project the resource structure in 1990. First, as several lagged endogenous variables are included as predetermined variables, the projections are made yearly from 1977 to 1990 with the projections for one year being used as the lagged variables of the next year. Second, only exogenous variables are used to project endogenous resource use in 1990. The exogenous variables are predicted to 1990 by simple, linear time trends estimated from the same time period as the reduced form estimates. These assumptions form the basis of the projections listed as Alternative I. Alternatives II and III assume that future structural changes will cause the reduced form estimates to underestimate and overestimate, respectively their projections by ten percent. When only exogenous variables are used to project, Alternatives II and III underestimate and overestimate the exogenous projections.

These procedures and assumptions are used to predict future U.S. agricultural resource organization in 1990. For the first method, the inputs or resources are specified within systems and the reduced form models then estimated. For the second method, the exogenous variables in the system are specified and the projection models estimated using only the exogenous variables. The systems and reduced form and projection models are presented in the next section; the predictions in the section following that.

Reduced Form Models

For direct estimation of the reduced form coefficients the inputs analyzed in the three previous chapters are specified in four systems of equations. Two methods are utilized to project to 1990. The current endogenous variables in each system are regressed upon the predetermined variables in that system to obtain the reduced form coefficient estimates in the first method. In the second the current endogenous variables are regressed upon only the exogenous variables in that system. The second method is used if the first method results in outrageous projections to 1990.

Farmers' expenditures for machinery and building and land improvements are grouped with hired and family farm labor and farmers' expenditures for fuel and oil and electricity for farm use. The average number of acres per farm at the end of the year and the current input prices are also included as endogenous variables. These endogenous variables are regressed upon lagged farmers' expenditures for building and land improvements, fuel and oil, and electricity, the lagged number of family farm workers, the average farm size at the beginning of the year, and the lagged prices of machinery, building and fencing materials, farm labor, and fuel and oil, all relative to the lagged prices received by farmers. The exogenous variables included in this first system are current values of total cropland acreage, farmers' ratio of equity to outstanding debt, the price of metals and metal products, the nonfarm wage rate, and the stock of farm buildings; lagged values of national net farm income, variation between expected and actual net farm income, the nonfarm to farm wage ratio, and that ratio multiplied by the national unemployment rate; and time variables consisting of the last two digits of the year and the square of the time variable.

Farmers' expenditures for operating inputs in aggregate are grouped with these current endogenous variables: hired and family farm labor, average farm size in acres and the prices of aggregate operating inputs and machinery, the farm wage rate, and the per acre value of U.S. farmland, all relative to the prices received by farmers. The lagged endogenous variables within the system are family farm labor, average farm size, and aggregate operating input price, farm wage rate, and machinery price, all relative to all prices received by farmers. The exogenous variables include the farmers' equity ratio, the nonfarm to farm wage ratio, that ratio multiplied by the national unemployment rate, the nonfarm wage rate, and a time variable consisting of the last two digits of the year.

The crop input system consists of farmers' expenditures for seed, fertilizer and lime, and pesticides, the prices of each relative to prices received for crops, the number of farms in the U.S., and the index of the ratio of all prices received to all prices paid by farmers. These current endogenous variables are regressed upon the lagged values of all eight endogenous variables and the exogenous variables to obtain the reduced form estimates. The exogenous variables included in the system are the farmers' equity ratio, national net farm income, the variation between expected and actual net farm income, the nonfarm wage rate, an index of U.S. agricultural exports, national personal disposable income, and a time variable consisting of the last two digits of the year.

Feed expenditures by all farmers is specified together with the feed price relative to livestock prices, the number of farms, and the index of the ratio of all prices received to all prices paid by farmers. The lagged endogenous variables are the number of farms and the two price ratios. The exogenous variables are the farmers' equity ratio, national net farm income, an index of U.S. agricultural exports, national personal disposable income, and a time variable consisting of the last two digits of the year.

The first two systems project unreasonable values using the reduced form models of the first method. Hence, for these two systems the second method of using only the exogenous variables for projecting is used. The last two systems yield reasonable projections using the first method. The first method is preferred if the results are reasonable because of the loss of information when lagged endogenous variables are deleted from the model.

The estimates of the coefficients of these models used in projecting resource use are in Appendix B. The estimated time trend equations for the exogenous variables are in Appendix B. With these estimates the organization and use of agricultural resources can be predicted to 1990. These predictions are in the next section.

Predictions to 1990

The task of predicting the far future is always accompanied by large error in those predictions. In this study econometric models of agricultural resource use predict the usage levels in 1990. Even though these models explain most of the variation in the years from which data are collected, the error increases as projections fall outside of the range of observations. Future unmeasurable shocks add greater uncertainty to these projections. Error in predicting the predetermined variables compounds the error in projecting the endogenous variables.

The projection error due to uncertainty of future unexperienced conditions and their effects upon resource use is unknown. For example, the bureaucratic rationing of gas in agriculture has not been experienced in the data years of this study or even anytime when agricultural fuel use has been at its present levels. The effect of this rationing upon the substitutes and complements of fuel cannot be estimated by the models in this study. The effects of mandatory soil loss controls and other new features cannot be estimated by models in this study either.

To estimate the sensitivity of the endogenous variable projections to errors in predicting the predetermined variables, two alternative projections are made. The predictions of predetermined variables are adjusted up and down by ten percent and new projections of the endogenous variables are made.

Under Alternative I exogenous variables are predicted by linear time trends and the alternative and reduced form models are used to project to 1990. Alternatives II and III should be used to view the sensitivity of individual resource projections; Alternatives II and III should not be used for comparison between resources. To analyze these projections, Alternative I is used to compare the relative resource mix projections and Alternatives II and III are used to estimate the sensitivity of individual resource projections.

Expenditures for farm machinery in 1990 are projected to be 4.6 billion dollars (1967 value) (Table 7.1). This is eighteen percent greater than the 1977 level and eight percent greater than the 1970 level. This projection is quite sensitive to the predictions of exogenous variables; a ten percent variation in the latter predictions causes an eighty-seven percent variation in machinery expenditure projections. Assuming that national net farm income continues to decline slowly or remains fairly steady, machinery purchases by farmers are predicted to rise by fifteen to twenty percent by 1990 from the 1977 level.

Farmers' expenditures for building and land improvements are

Table 7.1. Projections of farmers' expenditures for machinery, building and land improvements, fuel and oil, electricity and aggregate operating inputs; and the levels of hired and family farm labor in 1990 under alternative assumptions[a]

Resource	Past levels 1970	Past levels 1977	1990 Projections: Alternatives I	II	III
	(million 1967 dollars)				
Machinery	4,270	3,896	4,595	8,591	599
Building & land improvements	1,659	1,965	2,052	800	3,303
Fuel & oil	1,608	2,018	2,027	2,391	1,663
Electricity	310	487	597	512	681
Hired labor[b]	1,175	1,296	894	752	1,036
Family labor[b]	3,348	2,856	2,152	2,369	1,934
Aggregate operating inputs	24,857	27,448	35,365	38,599	32,131

[a]Due to unrealistic results from reduced form models these projections are from regressions on exogenous variables only.

[b]Thousands of persons.

projected to increase as well. Improvements expenditures in 1990 are projected to increase by four percent from the 1977 level under Alternative I compared to an eighteen percent increase in machinery expenditures. The projection of expenditures for improvements is quite sensitive to the predictions of exogenous variables. Under Alternatives II and III a ten percent error in exogenous predictions is estimated to cause a sixty-one percent change in projections of expenditures for improvements. Under conditions of slowly falling national net farm income and farmers' equity ratio, expenditures for improvements are predicted to increase slightly, approximately five percent, by 1990.

The rate of increase in improvements expenditures is less than the increase in machinery expenditures so the machinery to building and land improvements ratio is expected to increase from 1977 to 1990. Future production is estimated to need more machinery and less buildings and land improvements such as terraces and irrigation equipment. Since these are aggregate measures of machinery and improvements, substitutions within these categories cannot be predicted, but in aggregate the use of machinery will increase relative to the use of improvements for future production in the U.S.

Prediction error of the exogenous variables causes less variation in absolute and proportional terms in the projections of expenditures for building and land improvements than in the projections of machinery expenditures. Underestimation of predicted values of exogenous variables causes the projection of machinery expenditures in 1990 to be larger and the projection of expenditures for improvements to be smaller than the projections made using the unadjusted exogenous predictions; overestimation causes the opposite effects. The inverse reactions to variations in exogenous variables are interesting. The effect of a future rate of decline in national net farm income being slower than the present rate of decline would be a larger increase in machinery expenditures and a smaller increase to perhaps a decrease in expenditures for improvements. Hence, future production would be using even more machinery relative to building and land improvements.

Energy use on the farm is expected to increase by 1990 but not in the same proportions as machinery expenditures. Assuming the linear predictions of the exogenous variables, farmers' expenditures for fuel and oil in 1990 are projected to be less than one percent greater than the 1977 level and twenty-six percent greater than the 1970 level. Under the same assumptions 1990 expenditures for electricity increase by twenty-three percent from 1977 levels and ninety-three percent from 1970 levels.

A ten percent variation in the predictions of exogenous variables causes an eighteen percent difference on projections of fuel and oil expenditures and a fourteen percent difference in projections of electricity expenditures. Under Alternative III, which assumes the linear trends overestimate the exogenous predictions by ten percent, expenditures for fuel and oil in 1990 are projected to decline by eighteen percent from 1977 levels. Under all three alternatives the use of electricity is projected to increase by 1990. If Alternative II is true, fuel and oil expenditures are projected to increase proportionally more than electricity expenditures.

Assuming the present trends in the exogenous variables to continue, the total farm labor force is projected to decline by twenty-seven percent or about one million people by 1990 since 1977. Proportionately, the hired farm labor force is estimated to decline more, thirty-one percent, but in absolute numbers the family labor force is projected to decline more between 1977 and 1990. Using the linear trends for the exogenous variables the number of family workers in 1990 is projected to be just over two million persons and the hired labor force, about nine hundred thousand persons.

Varying the exogenous time trends by ten percent varies the projections of the hired labor force by sixteen percent and the family labor force by ten percent. In all three alternatives the hired and family labor forces are projected to decline from 1977 levels. Underestimation of the exogenous predictions result in higher projections in the family labor force and lower projections in the hired labor force. Overestimation causes the opposite results.

The substitution of machinery for labor is projected to continue.

Under Alternative I farmers' expenditures for machinery in 1990 is projected to be eighteen percent larger than the 1977 level while the total labor force is expected to decline by twenty-seven percent. Hence, if no exogenous shocks occur the machinery/labor ratio is projected to increase in the future and U.S. agriculture will become more and more dependent upon capital technology to produce.

Farmers' expenditures for all operating inputs are projected to increase in all three alternatives for 1990. Under Alternative I the expenditures are estimated to be twenty-nine percent greater in 1990 than in 1977. A ten percent variation in the predictions of the exogenous variables causes a nine percent variation in the projection of expenditures for operating inputs in aggregate. These projections show the continuing trend towards purchased inputs and away from farm-produced, nonpurchased inputs.

Projections for 1990 of farmers' expenditures for the crop inputs analyzed in this study are fairly stable and indicate an increase over 1977 levels (Table 7.2). Expenditures for seed are projected to increase by nine percent between 1977 and 1990. The projections do change between alternatives but only about eight percent. Only under Alternative III do projected seed expenditures decrease and then by less than one percent. Seed expenditures are projected to increase the least of the three crop inputs analyzed.

Table 7.2. Projections of farmers' expenditures for seed, fertilizer and lime, pesticides, and feed and the number of farms in the U.S. in 1990 using reduced form models under alternative assumptions

Resource	Actual levels 1970	Actual levels 1977	1990 Projections: Alternatives I	II	III
		(million 1967 dollars)			
Seed	828	1,094	1,189	1,286	1,084
Fertilizer & lime	2,716	3,364	4,529	4,424	4,306
Pesticides	957	1,212	1,882	1,824	1,851
Livestock feed	7,949	7,441	9,814	8,234	11,140
Number of farms[a]	2,902	2,680	1,050	1,501	810

[a]Thousands of farms at the end of the year. These estimates are from the livestock feed system.

Farmers' expenditures for fertilizer and lime are projected to have the largest absolute increase of the crop inputs. Fertilizer and lime purchases are predicted to be about 4.5 billion dollars (1967 value) in 1990, a thirty-five percent increase from 1977. Projections of fertilizer and lime expenditures under Alternatives II and III are estimated to vary less than five percent from the projection under Alternative I.

Since a large percentage of cropland was already fertilized in 1977, the projected increase to 1990 must come from other causes. Increasing knowledge of crop response to fertilizer and lime may cause farmers to apply rates closer to the optimal level. New crop varieties may increase the productivity of fertilizer and lime thus increasing the demand for these inputs.

Pesticide expenditures are projected to have the largest proportional increase between 1977 and 1990 of the three crop inputs. The projection under Alternative I is fifty-five percent larger than the 1977 level. Projections under Alternatives II and III are estimated to vary by three percent from Alternative I. Total expenditures for pesticides by farmers in 1990 are projected to be just under two billion dollars (1967 value) if present trends continue. The relatively large increase in the use of pesticides is due to the continual development of new pesticides and the continual substitution of pesticides for other inputs in the resource mix.

Expenditures for feed are projected to increase by thirty-two percent between 1977 and 1990. The projections under Alternatives II and III vary by sixteen percent from the projection in Alternative I. Increased feed purchases in 1990 also indicate an increase in consumer meat demand since feed demand is derived from meat demand.

The number of farms is projected to decline drastically by 1990. Under Alternative I a decrease of sixty-one percent is estimated; under Alternative II, a forty-four percent decrease; and under Alternative III, a seventy percent decrease. The historical decline in the number of farms is predicted to continue. The level of inputs is predicted to increase per farm; even labor is predicted to increase per farm in 1990 since the projected decline in farm numbers is greater than the projected decline in farm workers.

Summary and Implications

The future levels of resource use are of interest to many people close to agriculture. In this chapter models are developed to predict these future levels of resource use. With these predictions, farmers and agribusinesses can plan for the future and its predicted needs and policy makers have a better knowledge of what lies in the future and how best to guide and shape policies for the future.

Although reduced form models are estimated for the four systems analyzed, two sets of these models project unreasonable values for

1990. For these two sets, models using only exogenous variables are estimated and used to project resource use in 1990. For the systems of crop inputs and livestock feed the reduced form models perform well and are used for projecting resource use.

The use of all purchased inputs is predicted to increase while labor employment and the number of farms are predicted to decrease. The mix of resources is projected to change between 1977 and 1990 as well. Capital continues to substitute for labor but the labor force is projected not to decline as fast as the number of farms does.

The level of machinery expenditures is projected to increase by eighteen percent between 1977 and 1990 under Alternative I. The machinery increase is greater than the four percent projected for expenditures for building and land improvements for the same period. This difference indicates a shift or substitution of machinery for improvements.

Farmers' expenditures for energy are projected to increase by five percent by 1990. Most of this increase comes from the twenty-three percent increase projected for electricity use since fuel and oil expenditures are projected to increase by less than one percent. These projections show a fairly constant expenditures for fuel and oil to 1990 and increasing use of electricity. This leveling off of fuel and oil demand is projected to occur without governmental intervention nor without the large oil price increases of the most recent years. The increase in the use of electricity relative to fuel and oil predicts an increasing demand for additional electrical power plants.

The stable expenditures for fuel and oil coupled with the projected increase in machinery purchased indicate increasing energy efficiency in farm machinery. This efficiency may come from the machines being more efficient or from more efficient use of the machinery decreasing use per acre. These projections are made without assuming any government intervention to reduce fuel usage; the projections indicate what lies in the future as agriculture adjusts its resource mix to the economic environment. These projections show U.S. agriculture adjusting to the current energy situation by itself.

Projections of farmers' expenditures in 1990 for seed, fertilizer and lime, pesticides, and livestock feed are higher than 1977 levels. Except for seed expenditures under Alternative III the expenditures for these three inputs are projected to increase from 1977 levels in all alternatives. Expenditures for seed are predicted to rise by nine percent between 1977 and 1990; fertilizer and lime expenditures, by thirty-five percent; pesticide expenditures, by fifty-five percent; and feed expenditures, by thirty-two percent.

Even though expenditures for these inputs are projected to increase, the 1990 mix of the three crop inputs is different from the 1977 mix. Expenditures for seed are projected to remain the smallest in absolute terms and to decrease relative to both fertilizer and lime and pesticide expenditures. The ratio of pesticide to fertilizer and lime expenditures is projected to increase from 0.36 in 1977 to 0.41 in 1990. Expenditures for fertilizer and lime are projected to remain the largest item in 1990 of these crop inputs.

The crop input supply sector of U.S. agriculture should expect to supply more of all three inputs, and to increase production of pesticides relative to fertilizer and lime relative to seed. However, these projections cannot predict the effect of governmental intervention. If rulings restrict the pesticide supply, farmers' expenditures for seed and fertilizer and lime may increase relative to pesticide expenditures.

Fertilizer and lime expenditures are projected to increase relative to farm machinery expenditures and both are projected to increase above 1977 levels. This shift in importance indicates future production will be accomplished with greater fertilizer and lime input relative to the machinery input. The projected increase in pesticide expenditures relative to machinery expenditures indicates the trend of substituting chemical for mechanical pest control to be continuing.

Since expenditures for feed are projected to increase while farm numbers are projected to decline, the future livestock farm is predicted to continue to increase in size. This is a continuation of present trends towards larger livestock operations. Increased feed purchases in 1990 indicate an increase in consumer meat demand.

Farmers' expenditures in 1990 for all operating inputs are projected to increase by twenty-nine percent over the 1977 level; all alternatives project an increase to 1990. The projected increase in the use of all operating inputs relative to machinery may reflect two conditions. The price of machinery is increasing relative to all prices received by farmers, thus the need to raise the marginal productivity of machinery. Also, the productivity of operating inputs may be increasing and (or) farmers are adjusting operating input usage up to optimal levels.

The farm labor force is projected to decrease by twenty-seven percent or slightly more than one million people between 1977 and 1990. The 1990 work force is projected to include just over three million people: slightly more than two million family workers and about nine hundred thousand hired workers. Proportionally the hired farm labor force is estimated to decline more than the family labor force but family labor is projected to decline the most in absolute numbers.

From these projections U.S. agriculture is estimated to continue in the trend of utilizing capital-intensive technology. Machinery purchases and expenditures for all operating inputs are projected to increase relative to the 1990 projected farm labor force.

Whether this trend of capital for labor substitution continues in the face of rising energy prices and potential cutbacks in energy supplies is not estimated in this study.

The number of farms is projected to decrease by sixty-one percent from 1977 to just over one million farms in 1990. Obviously, this large decrease causes all projected inputs to increase per farm. Even labor is projected to increase per farm: from about one and one-half workers per farm in 1977 to about three workers per farm in 1990. Increases in machinery expenditures will not keep pace with the decline in farm numbers; machinery expenditures per farm worker are projected to increase but not enough to maintain the present worker per farm ratio.

For communities the loss of farm workers and the decline in farm numbers means a decline in demand for community services and a potential decaying of the present community. However, the projected increase in workers per farm is an indication that demand for some community services will not decline as fast as farm numbers. Medical, educational, and other personal services may not decline as rapidly as farm numbers but local commercial services may suffer. As farms become fewer and thus larger, local markets may be bypassed in favor of regional markets. Hence, indirectly, these projections of resource use project a decrease in demand for local services in agricultural and nonagricultural areas.

These predictions are based on the assumption that present trends in the conditions surrounding agriculture will continue.

They do not predict what changes may occur if shocks previously unknown (e.g., fuel rationing) would occur in the future.

Predictions are needed so planners and policy-makers can prepare for the future. With these predictions directions of movement in resource use can be estimated. Then plans and policies can be formulated to prepare for and (or) change the future.

CHAPTER VIII. SUMMARY AND IMPLICATIONS

The structure and mix of resources used in U.S. agriculture is analyzed in this study. Resource structure is used in this study to refer to the mix of resources used, the size and number of farms, and the demand, supply, and production functions of agriculture. The structural coefficients, the parameters of the demand, supply, and production functions, determine the structural organization of agriculture, the mix of resources and the size and number of farms. The structural organization of agriculture is physical and directly measurable; the structural coefficients are discernible as underlying, intrinsic relationships.

This study estimates part of the resource structure of U.S. agriculture. The factors affecting the demand for resources and groups of resources at the national level are analyzed by econometric methods. The significance, magnitude, and direction of the impact of these factors is determined. Elasticities of demand with respect to various variables are calculated from this analysis. When they are available, past elasticity estimates are compared to present estimates.

The analysis of national demand for resources is broken into three main sections: machinery and building and land improvements, labor, and operating inputs. Farm labor is divided into its hired and family portions for analysis. In addition to analyzing aggregate demand for operating inputs, the separate categories of seed, fertilizer and lime, pesticides, feed, fuel and oil, and electricity are analyzed.

The second major part of this study projects the future mix or structure of agricultural resources at the national level in 1990. From this analysis future movements and changes in the resource structure are predicted. Potential effects and (or) problems that may occur under the projections are pointed out and discussed.

Models of Resource Structure

Prior to the analysis several models of resource demand and investment are presented and discussed. The variables used in model formulation and the reasons for including them are reviewed.

Prices of resources and products have an important part in resource structure analysis. Prices determine the optimal mix of resources to be used; other variables explain deviations from these levels. Net farm income is used to estimate returns to durable resources and expectations of future financial capabilities; income will often determine the variation from the optimal resource level. Equity is used as an indicator of debt payment capacity and as an estimate of ability to weather hard financial times.

The nonfarm/farm income and wage ratios are used to explain farm employment. Higher ratios cause workers to try to find nonfarm jobs. Unemployment may keep a worker from moving and is used to capture this effect.

Average acreage per farm and the number of farms are included in models to capture the effect of size upon resource demand. Lagged stocks and expenditures are used because of the tendency to repeat last year's practices and to develop other models of resource demand. Many other variables affect resource demand over time but these may change so slowly that incorporating them together into a time variable is the practical approach.

These variables are used to develop several models of resource demand and investment. Input-output and input-input price ratios are used with other variables.

Expectation and adjustment models are developed. One expectation model assumes that the expected change in income for the current year is proportional to the error made in estimating income last year; this assumption is incorporated into a simple model and the expectation model is formulated. The adjustment model used in this analysis assumes a Koyck or geometrically declining distribution of coefficient values; for annual data as used in this analysis this is not too restrictive an assumption. A constant adjustment rate between optimal and actual resource levels is used to develop the adjustment model.

Risk is included in this analysis by estimating the variation between expected and actual income. This variation is used as another variable determining demand. It is assumed to have a dampening effect upon resource demand and investment.

The models presented in Chapter II are general in nature. They are adopted to fit the needs of individual resource demand analysis.

Statistical Procedures

The selection of the statistical procedure appropriate to the goals of the analysis and the problems and conditions encountered in the analysis is just as important to econometric analysis as is the correct specification of the economic model. For the first part of this study the structural coefficients are estimated; in the second part projections of future resource levels are estimated. These two goals use two different statistical procedures.

Resource demand is assumed to be interdependent within resource groups. Autocorrelation may be present in the error terms also. Hence, a system approach that corrects for autocorrelation is needed to estimate the structural coefficients. Several Monte Carlo studies show two-stage least-squares (2SLS) to have the best characteristics in terms of both bias and mean square error but is quite sensitive to high degrees of correlation between the independent variables; the limited information maximum likelihood estimator is not as sensitive to correlations between independent variables. Fuller's (1977b) modified limited information maximum likelihood estimator (MLIML) is selected over 2SLS for use in this study due to the probability of correlations between independent variables in this study and the ability to select for asymptotically, nearly unbiased estimates. Fuller (1978) describes a procedure for correcting for autocorrelation in one equation within a system by a one-step Gauss-Newton procedure.

To project values of endogenous variables two methods are available. First, the structural equations may be estimated and used to calculate the reduced form models. Second, the reduced form models may be estimated directly. This latter procedure is used in this study, thus avoiding possible specification error in the structural equations. Projections are made from estimates of the predetermined variables using the reduced form models.

Empirical Estimates of National Resource Demand Functions

The structural coefficients of demand for resources by farmers are estimated by the statistical procedures outlined in the previous section. General models of demand and investment are discussed briefly in this chapter and more fully in Chapter II; these general models are used to develop specific models for the resource being analyzed.

Agricultural resource demand is analyzed on the national level. Data are from 1946 to 1977 with 1945 for lagged observations.

The analysis is done on several resources and groups of resources. Investments in machinery and in building and land improvements are analyzed separately in Chapter IV. Farm employment is divided into hired labor and family labor and analyzed in Chapter V. The demand for operating inputs in aggregate is analyzed and then the separate categories of fuel and oil, electrictiy, seed, fertilizer and lime, pesticides, and livestock feed are analyzed in Chapter VI. A more detailed summary of the empirical results is in each of these chapters; a brief summary of the estimates and implications is given here by resource.

Machinery

Farm machinery includes tractors, trucks, and automobiles for farm use; planting, harvesting, and tillage equipment; and other mechanical equipment used in the farm business. Several formulations of machinery demand models are used to achieve theoretically correct signs on the prices in those models.

Farmers' demand for machinery is estimated to be elastic with respect to the current machinery price in the long run. The long-run elasticity of machinery demand with respect to the machinery price is estimated to be between -1.0 and -1.4; the short-run own price elasticity is estimated to be -0.4. Since price ratios are used, machinery demand is estimated to be elastic with respect to all prices received by farmers and with respect to the farm wage rate.

Previous estimates indicate the machinery demand elasticity with respect to the machinery price to be increasing over time. Machinery is now an integral part of the farm business replacing horses, and machinery stocks have been built up. The greater response to prices may be a reflection that machinery purchases are now adjustments rather than additions to the stock level. Higher general education levels of farmers and better knowledge of machinery production functions also increase demand's responsiveness to price changes.

Machinery demand is quite responsive to total crop acreage. The elasticity of machinery demand with respect to total acreage is estimated to be 0.9. If a ten percent land set-aside program is implemented as an overall, national policy, machinery demand is estimated to decline by nine percent if all other factors are constant. So machinery dealers may be hurt under such a policy even though it is meant to raise farm income.

National net farm income and the variation between expected and actual net farm income are estimated to have significant positive and negative effects, respectively, on machinery demand. The income elasticity of machinery demand is estimated to be between 1.1 and 1.3. The response of machinery demand to income variation is very inelastic.

If the land set-aside policy is implemented, farm machinery dealers may suffer from a decline in sales or rejoice in an increase in sales. The determining factor is how responsive is farm income to the land set-aside. If farm income increases by ten percent with a ten percent land set-aside, machinery demand is estimated to increase due to the effects of income and acreage. The ten percent decrease in crop acreage is estimated to cause a nine percent decrease in machinery demand; the ten percent increase in farm income is estimated to cause an eleven to thirteen percent increase in machinery demand. The increase is larger than the decrease in machinery demand. If a ten percent land set-aside program increases farm income by less than nine percent, these response estimates show machinery demand will decline.

Other, slowly changing variables have a significant, positive effect on machinery demand. These results and other, less successful models are discussed in Chapter IV.

Building and land improvements

Building and land improvements include new construction, additions, and major improvements of service buildings, other structures, fences, windmills, wells, dams, ponds, terraces, drainage ditches, tile lines, other soil conservation facilities, and dwellings not occupied by farm operators. Farmers' demand for improvements behaves as expected in response to its own price and the prices of complements and substitutes.

The demand for building and land improvements is very elastic with respect to the price of building and fencing materials. The own price elasticity of demand is estimated to be from -3.11 to -3.7. Thus, demand for improvements is estimated to change by more than three times the proportional change in the price of building and fencing materials if all other conditions are constant. Other factors being stable the continuing increase in the price of building and fencing materials relative to all prices received by farmers (e.g. Fig. 4.2) will cause demand for improvements to decrease in the future.

On the basis of the sign on the estimated coefficients, fuel and oil are estimated to be substitutes for improvements since the coefficients are positive. The demand for improvements is estimated to be elastic with respect to the price of fuel and oil. As oil prices rise in the future the demand for building and land improvements is estimated to rise at a faster rate if all other factors are constant.

The response of demand for improvements to the farm wage rate is negative and inelastic. Farm labor is estimated to be a complement of building and land improvements since many buildings are used for livestock production which requires a large amount of labor. As the farm wage rate increases relative to all prices received, the demand for improvements is estimated to decrease at a proportionally slower rate.

Farmland is estimated and expected to be a substitute for building and land improvements. The cross-price elasticity of demand for improvements is estimated to range between 0.9 to 1.4. Hence, if the trend of rising land prices relative to all prices received continues, building and earthen contractors are estimated to receive greater demand for their services unless other factors decrease demand for improvements.

The stock of buildings has a significant, negative effect on demand for building and land improvements. The negative effect is assumed to be the simple effect of the stock upon demand; that is, if the stock of buildings is high, the demand for improvements due to other variables will be dampened by the stock of buildings.

The other, slowly changing variables have a positive effect on demand for building and land improvements. The growth in demand for improvements over time is small but significant.

Hired farm labor

Hired farm labor is the non-family component of farm labor. Hired labor response to the farm wage rate is very inelastic; the elasticity of hired labor demand with respect to the farm wage rate is estimated to be -0.6 to -0.9. These estimates are higher than previous estimates of the hired labor demand elasticity with respect to the farm wage rate. Increasing education and skill and improved communication may have increased farm workers' mobility between farm and nonfarm jobs, thus increasing the responsiveness to the wage rate.

The elasticity of hired farm labor demand with respect to the price of fuel and oil is estimated to be 0.41. Hired labor and fuel and oil are substitutes but not perfect substitutes. If the recent trends of higher crude oil prices continue into the future and other factors overpower this effect, the demand for hired farm labor is expected to increase although at a lower rate than the crude oil price.

By summing the elasticities of all price ratios and changing the sign, the elasticity of demand for hired farm labor with respect to all prices received can be estimated to be between 0.3 and 0.55. Previous estimates of this elasticity are lower than this estimate indicating an increase over time in the responsiveness of hired farm labor demand to all prices received by farmers. Better education and skill and improved communication and transportation explain the increase in responsiveness. These conditions seem to be continuing and the elasticity of demand probably will continue to increase as well.

The demand for hired farm labor is positively correlated with the demand for family farm labor. The estimate of this relationship varies with the model specification from an eight to fifteen decrease in hired labor demand if the family labor force decreases by ten percent.

Average farm acreage explains hired farm labor demand better than the number of farms. The elasticity of hired labor demand with respect to average farm size is estimated to be -1.55. The hired labor force is estimated to decrease faster than the average farm acreage increases. This relationship is indicative of the labor-machinery substitution; larger machinery allows one worker to cover more acres.

The labor-machinery substitution is also evident by the negative coefficient estimated on machinery expenditures. The response of hired labor demand to machinery expenditures is very inelastic; a ten percent increase in machinery expenditures is estimated to cause a two percent decrease in hired labor demand.

Previous studies show current hired labor demand to be a function of past hired labor demand. These studies show the importance of past demand levels in explaining current levels to be declining over time. In this study the mobility of labor has increased to the point where past demand levels do not have a significant effect upon current demand.

Slowly changing variables have a positive effect on hired labor demand over time. This effect has been overshadowed by the effects of other variables since the hired labor force has decreased over time.

<u>Family farm labor</u>

The distinction between the demand for and supply of family farm labor is difficult to perceive because demand and supply decisions are made by the same people. This study uses models of family labor employment and not necessarily models of demand or supply.

The short-run elasticity of family farm employment with respect to the nonfarm to farm hourly wage ratio is estimated to be -0.3; the long-run elasticity is estimated to range from -0.5 to -0.65. Family farm employment is estimated to decrease as the nonfarm wage rate increases relative the farm wage rate but the response is inelastic. So if hired farm workers were to obtain a higher farm wage rate, the number of family workers would increase in response to the decreasing nonfarm to farm wage ratio.

The elasticity of family farm employment with respect to the nonfarm to farm annual income ratio is estimated to be -0.13. This elasticity estimate is higher than the estimates from earlier data years by Heady and Tweeten (1963). The increase in family labor mobility has occurred for the same reasons that hired labor mobility has increased. Better education and skill and improved communication and transportation has given farm labor the ability to move and the knowledge of when to move and where to move to.

The national unemployment rate does hamper family labor movement if that rate is high enough even if the nonfarm to farm wage or income ratio is large. Changes in family farm employment are quite inelastic with respect to the unemployment rate. The critical level of national unemployment above which family workers move from nonfarm to farm jobs is estimated to be eleven percent of the national labor force. Above eleven percent the movement back to farming by family occurs but the response is still quite inelastic.

As the number of farms decreases and the average acreage per farm increases the number of family farm workers is estimated to decrease. The response is small and inelastic however. The average acreage explains the family employment level better than the number of farms.

The equity ratio and national net farm income are estimated to have small but significant positive effects upon family employment. Government programs that increase farm income do increase family farm employment but the small effect from the higher income is easily overshadowed by other factors affecting family employment. Other, slowly changing variables have a significant, negative effect upon family employment.

Aggregate operating inputs

The measure of aggregate inputs includes feed, seed, feeder livestock, fertilizer and lime, building repairs, fuel and oil, machinery repairs, pesticides, utilities, custom work, machine hire, ginning, interest on nonreal estate debt, and other miscellaneous supplies. These inputs are for farm use only. Those operating inputs analyzed individually are included in this aggregate measure.

The elasticity of demand for operating inputs in aggregate with respect to its own price is estimated to be between -1.1

and -1.5. Heady and Tweeten's (1963) least squares estimate of this elasticity is -0.6. A higher elasticity from more recent data is expected since a larger proportion of inputs is purchased from nonfarm sources and prices are more important. As the proportion of all inputs purchased increase, the own price elasticity of demand is expected to continue to increase and operating inputs in aggregate will become more responsive to price changes.

The best estimate of the elasticity of demand for operating inputs in aggregate with respect to the value of farmland is 0.47; farmland is a substitute for operating inputs. If the recent trend of farmland values increasing relative to all prices received continues, the aggregate demand for operating inputs is estimated to increase at about half the rate that farmland value is increasing.

Aggregate demand for operating inputs is inelastic with respect to last year's machinery price. A ten percent rise in machinery prices this year is estimated to produce a four percent rise in operating input demand next year. The current machinery price is estimated to have no significant effect on operating input demand. Hence, the substitution between machinery and operating inputs is evident as a lag effect.

The demand for operating inputs is estimated to become more responsive to changes in all prices received by farmers over time. Heady and Tweeten (1963) estimate the elasticity of operating input demand with respect to all prices received to be 0.2 to 0.5;

this elasticity is estimated to be 0.7 to 1.1 in this study. The higher proportion of inputs purchased and the greater knowledge of input productivity have caused this elasticity to increase. Thus, the demand for operating inputs can be expected to fluctuate more or input prices will. Input supply firms will have to be more attentive to market conditions to remain solvent since farmers now respond with greater changes.

As the equity ratio falls, the demand for operating inputs in aggregate is estimated to rise significantly but inelastically. A ten percent fall in the equity ratio is estimated to cause a one to three percent increase in operating input demand. By increasing the use of operating inputs, the productivity of labor and durable resources may increase and thus the return to these resources will increase. If returns increase liabilities can be paid and equity increases. As the equity ratio falls, machinery and labor demand fall so to keep production fairly constant the use of operating inputs must increase.

Variation between expected and actual income has a small negative effect on demand for operating inputs. As risk of potential returns increases farmers show their risk-aversion characteristics and decrease use of inputs.

Over time demand for operating inputs is increasing. Improved knowledge of input productivity and adoption of new practices have increased operating input use.

Fuel and oil

Farmers' expenditures for fuel and oil include expenditures for crop and livestock enterprises. Fuel and oil used in production, marketing, repairs, overhead, and other farmwork are counted. Only fuel and oil used in and for farm business are counted. The fuel and oil used by automobiles for farm business are included.

The demand curve for fuel and oil is expected to be negatively sloped. Empirically, this was difficult to find. Over the past few decades the consumption of fuel and oil in agriculture has been increasing even though its price has been increasing relative to all prices received by farmers. The individual farmer will adjust demand to prices, but because these are national data this individual adjustment is lost amidst the influx and adoption of new technologies using fuel and oil in agriculture.

Mean square error is improved when the fuel and oil price is deleted from the model. Furthermore, empirically it is hard to find theoretically correct signs on any of the price ratios used in this analysis. The lagged machinery price has a significant effect upon demand but it is a positive effect instead of the negative effect expected from a complement.

Net farm income is estimated to have a positive, although inelastic, effect upon fuel and oil demand. A ten percent rise in net farm income is estimated to cause a three to five percent rise in fuel and oil demand. Higher income increases machinery purchases which increases the need for fuel and oil so income's effect upon fuel and oil demand is a secondary effect.

The effect of the stock of farm machinery on fuel and oil demand is positive but quite small. Total crop acreage has a large positive effect on farmers' demand for fuel and oil. These estimates show that the total land area farmed is a better determinant of fuel and oil demand than the total amount of machinery owned by farmers. Fuel and oil demand also increases over time due to slowly changing variables.

Electricity

Expenditures for electricity include all purchases of electricity for farmwork. Only electricity used in the farm business is counted; no home use is included.

The models of electrical demand using the data in original form fit the expectation model as formulated in Chapter II. The coefficients estimated are short-run coefficients except for the price coefficients which are long-range. The lagged expenditures variable is included in all models; without it coefficients are unstable and mean square error is larger. In models using logarithmically transformed data the lagged expenditures variable does not exert a significant influence upon electricity demand and elasticity estimates vary from those of other models.

The elasticity of electrical demand with respect to the price of electricity is estimated to be about -0.5 using original forms and -0.7 to -0.8 using logarithmic forms. Utility companies can increase profits by increasing prices because demand is estimated to decrease less than the price rise. Electrical demand elasticity with respect to the farm wage rate is estimated to range from 0.4 to 0.5. Demand elasticity with respect to all prices received by farmers is estimated to be 0.03 to 0.11 which is quite inelastic. Electrical demand is quite stable with respect to these prices.

The demand for electricity is quite elastic with respect to the price of fuel and oil. A ten percent rise in the price of fuel and oil is estimated to cause a thirteen to fourteen percent rise in the demand for electricity in the long-run with all other factors constant. These energy inputs are very direct substitutes for each other so electrical demand is very responsive to the fuel and oil price.

Net farm income has a significant effect using the data in original form but not in logarithmic form. When it is significant, the elasticity of electrical demand with respect to net farm income is estimated to be 1.55. As income has risen over the years the adoption of electricity and new technologies using electricity has increased as well.

Electrical demand is affected adversely by risk. The long-run elasticity of demand for electricity with respect to variation in income is estimated to be -0.2 to -0.3.

Seed

Expenditures for seed include only seed for crop production. The elasticity of seed demand with respect to its own price is estimated to be -0.45 in the long-run. Since the seed price enters the model relative to crop prices received by farmers and this is the only price ratio in the model, this elasticity estimate is the same for seed demand with respect to crop prices. These inelastic responses indicate two things; first, demand is fairly stable and second, seed companies can increase their prices and their profits because demand will not fall in proportional to the price rise.

Heady and Tweeten (1963) can not find a significant effect upon seed demand by seed price. The more recent data used in this analysis show seed demand responding to the price of seed. More seed is purchased now and not produced on individual farms as it was in earlier years.

The decline in the number of farms and the increase in farm size are estimated to decrease seed demand. These trends in farm numbers and size have accompanied seed quality increases and the substitution of other inputs for seed.

As with other inputs seed demand responds positively to net farm income. The estimate of demand response to changes in net farm income varies with the model formulated but in all cases the effect is direct, significant, and inelastic. Risk aversion has the expected effect on demand. The variation in net farm income has a very inelastic but negative effect upon seed demand.

Fertilizer and lime

Only farmers' expenditures for fertilizer and lime for use in crop production are included. Using the original data the elasticity of demand with respect to its own price is estimated to be -1.0 to -1.5. With logarithmically transformed data the demand elasticity is estimated to be -0.6 in the long-run. These differences may occur due to rapid increases in the use of fertilizer and lime in the middle of the period analyzed and the calculation process for the elasticities. The elastic responses may be true for past years as fertilizer prices dropped relative to crop prices and fertilizer use increased. The elastic responses also may reflect improved knowledge of the fertilizer and lime production functions and so more knowledgeable responses to price changes. The inelastic responses may reflect a more stable demand for fertilizer and lime after the adoption process of fertilizing practices is nearly complete. Heady and Tweeten's (1963) estimates are close to those using logarithmic data but are lower than those using original data. The elasticity is expected to increase with time as knowledge and use increase.

Seed is estimated to be a substitute of fertilizer and lime. The response of fertilizer and lime demand to the seed price is inelastic; a ten percent increase in the price of seed is estimated to increase fertilizer and lime demand by four to nine percent.

The demand elasticity of fertilizer and lime with respect to crop prices is positive but quite low; it is estimated to be 0.1 to 0.5. This estimate is less elastic than Heady and Tweeten's estimate. The variation in crop prices in recent years may explain this decrease in elasticity.

Farmers' demand for fertilizer and lime responds negatively to changes in the farmers' equity ratio. A decrease in their equity ratio will cause farmers to increase their use of operating inputs to increase production and thus income to pay debts. A ten percent decrease in the equity ratio is estimated to increase fertilizer and lime demand by four and a half to eight and a half percent.

The income elasticity of demand for fertilizer and lime is estimated to be 0.36. The variation in net farm income has a positive estimated coefficient indicating a risk loving characteristic in farmers but this coefficient is not significant in all models. Slowly changing variables exert a positive influence on fertilizer and lime demand.

Pesticides

Pesticides are herbicides, insecticides, fungicides, and other chemicals used in the soil or plants to minimize the effects of weeds, crop predators, and plant diseases. The elasticity of demand for pesticides with respect to its own price is estimated to be -1.1 to -1.6. Farmers are either very near the optimal level of pesticide usage and so adjust their expenditures to price changes. Or they do not have full information on the productivity of pesticides and so react drastically to price changes.

The income elasticity of pesticide demand is estimated to be 1.3. In periods of falling farm income, chemical companies should expect pesticide demand to fall at a faster rate. The variation in net farm income is estimated to have a significant, negative inelastic effect upon farmers' demand for pesticides. The slowly changing variables represented by the time variable are estimated to have a positive effect upon pesticide demand over time.

Feed

Farmers' expenditures for feed includes feed for beef cattle, swine, sheep, dairy cattle, and poultry for slaughter, replacement, and breeding. Feed for horses and mules doing farm work is included also.

The short-run elasticity of feed demand with respect to its own price is estimated to be -0.35 to -0.7; the intermediate-run elasticity is estimated to be -0.6 to -1.0. Previous estimates by Heady and Tweeten (1963) are higher than these estimates. Their estimate of short-run own price elasticity of feed demand is -1.0. In this case the increase in the input proportion purchased from nonfarm sources causes the elasticity to become more inelastic. Larger livestock operations of recent years which do not have the capacity to raise all their feed needs create a more stable demand for feed and thus decrease fluctuations as price changes. Since price ratios are used in the model the short-run elasticity of feed demand with respect to livestock prices is estimated to be 0.35 to 0.7; the intermediate elasticity is estimated to be 0.6 to 1.0

The feed demand response to changes in the number and size of farms is estimated to be elastic in the long run in both cases. The U.S. population has grown in numbers and affluence as farm numbers have declined and average farm acreage has increased. These relationships may not be direct cause and effects but more effects of other causes.

Feed is the only operating input analyzed in this study estimated to have direct but inelastic responses to changes in the equity ratio. Livestock production may improve the equity ratio more than the higher equity ratio cause increased livestock production. But the equity ratio does improve the mean square error when the ratio is included in the demand model.

National personal disposable income is estimated to have a positive but inelastic effect upon feed demand. As consumers' income increases meat demand increases which cause increases in feed demand.

Predictions of Resource Use

Predictions are needed to observe directions of movement in resource use. With these predictions farmers and agribusinesses can plan for the future and its predicted needs and policy makers have a better knowledge of what lies in the future and how best to guide and shape policies for the future.

The use of all purchased inputs is predicted to increase while labor employment and the number of farms are predicted to decrease. The mix of resources is projected to change between 1977 and 1990 as well. Capital continues to substitute for labor but the labor force is projected not to decline as fast as the number of farms does.

The level of machinery expenditures is projected to increase by eighteen percent between 1977 and 1990 under Alternative I. The machinery increase is greater than the four percent increase projected for expenditures for building and land improvements for the same period. This difference indicates a shift or substitution of machinery for improvements.

Farmers' expenditures for energy are projected to increase by five percent by 1990. Most of this increase comes from the twenty-three percent increase projected for electricity use since fuel and oil expenditures are projected to increase by less than one percent. This leveling off of fuel and oil demand is projected to occur without governmental intervention nor without the large oil price increases of the most recent years. The increase in the use of electricity relative to fuel and oil predicts an increasing demand for additional power plants.

The stable expenditures for fuel and oil coupled with the projected increase in machinery purchased indicate increasing energy efficiency in farm machinery. This efficiency may come from the machines being more efficient or from more efficient use of the machinery per acre. These projections are made without assuming any government intervention to reduce fuel usage; the projections indicate what lies in the future as agriculture adjusts its resource mix to the economic environment. These projections show U.S. agriculture adjusting to the current energy situation by itself.

Projections of farmers' expenditures in 1990 for seed, fertilizer and lime, pesticides, and livestock feed are higher than 1977 levels. Except for seed expenditures under Alternative III the expenditures for these three inputs are projected to increase from 1977 levels in all alternatives. Expenditures for seed are predicted to rise by nine percent between 1977 and 1990; fertilizer and lime expenditures, by thirty-five percent; pesticide expenditures by fifty-five percent; and feed expenditures, by thirty-two percent.

Even though expenditures for these inputs are projected to increase, the 1990 mix of the three crop inputs is different from the 1977 mix. Future production is projected to use more pesticides relative to fertilizer and lime and more of both pesticides and fertilizer and lime relative to seed. Expenditures for fertilizer and lime are projected to remain the largest of these crop inputs in 1990.

However, these projections cannot predict the effect of governmental intervention. If rulings restrict the pesticide supply, farmers' expenditures for seed and fertilizer and lime may increase relative to pesticide expenditures but this effect is not quantified in this analysis.

Fertilizer and lime expenditures are projected to increase relative to farm machinery expenditures; both are projected to increase above 1977 levels. This shift in importance indicates future production will be accomplished with greater reliance on fertilizer and lime than on machinery. The projected increase in pesticide expenditures relative to machinery expenditures predicts that the trend of substituting chemical for mechanical pest control will continue into the future.

Since expenditures for feed are projected to increase while farm numbers are projected to decline, the future livestock farm is predicted to continue to increase in size. This is a continuation of present trends towards larger livestock operations. Increased feed purchases in 1990 indicate an increase in consumer meat demand.

The farm labor force is projected to decrease by twenty-seven percent or slightly more than one million people between 1977 and 1990. The 1990 work force is projected to include just over three million people: slightly more than two million family workers and about nine hundred thousand hired workers. Proportionally, the hired farm labor force is estimated to decline more than the family labor force but family labor is projected to decline the most in absolute numbers.

From these projections U.S. agriculture is estimated to continue in the trend of utilizing capital-intensive technology. Machinery purchases and expenditures for all operating inputs are projected to increase relative to the future farm labor force.

The number of farms is projected to decrease by sixty-one percent from 1977 to just over one million farms in 1990. Obviously, this large decrease causes all projected inputs to increase per farm. Even labor is projected to increase per farm: from about one and one-half workers per farm in 1977 to about three workers per farm in 1990. Increases in machinery expenditures will not keep pace with the decline in farm numbers; machinery expenditures per farm worker are projected to increase but not enough to maintain the present worker per farm ratio.

For communities the loss of farm workers and the decline in farm numbers means a decline in demand for community services and a potential decaying of the present community. However, the projected increase in workers per farm is an indication that demand for some community services will not decline as fast as farm numbers.

These predictions are based on the assumption that present trends in the conditions surrounding agriculture will continue. They do not predict what changes may occur if shocks previously unknown (e.g., fuel rationing) would occur in the future.

In this analysis the structural coefficients of agricultural resource demand by U.S. farmers are estimated. When available, past estimates of the structural coefficients are compared to the estimates of this study. The usage levels and mix of agricultural resources at the national level in 1990 are predicted.

These results should be interpreted with two qualifications at least. While the models used in the analysis explain quite a bit of the variation in resource use, the estimates and predictions are made with some error; the effects of future events that have not occurred before cannot be estimated from this analysis. Keeping these qualifications in mind, the results of this study can be used by many people in and out of agriculture to plan for the future and (or) to estimate the effects of certain actions.

REFERENCES

Barr, Anthony J., J. H. Goodnight, J. P. Sall and J. T. Helwig
1976 A User's Guide to SAS76. Raleigh, North Carolina: Sparks Press.

Council of Economic Advisers
1978 The Annual Report of the Council of Economic Advisors. In Economic Report of the President. Washington, D.C.: U.S. Government Printing Offices.

Durost, Don
1979 Unpublished data on aggregate prices and expenditures. Economics, Statistics, and Cooperatives Service, United States Department of Agriculture, Washington, D.C.

Durost, D.D., and E. T. Black
1978 Changes in Farm Production and Efficiency, 1977. Statistical Bulletin No. 612. Economics, Statistics, and Cooperatives Service, United States Department of Agriculture, Washington, D.C.

Evans, C. D., and R. W. Simunek
1978 Balance Sheet of the Farming Sector, 1978. Supplement No. 1 to Agriculture Information Bulletin 416. Washington, D.C.: National Economic Analysis Division, Economics, Statistics, and Cooperatives Service, United States Department of Agriculture.

Fuller, Wayne A.
1977a "The Modified Limited Information Maximum Likelihood Estimator." Unpublished lecture notes. Statistics Department, Iowa State University, Ames, Iowa.
1977b "Some properties of a modification of the limited information estimator." Econometrica 45:939-954.
1978 "Estimation of a single equation in a system when the errors are autocorrelated." Unpublished class notes. Statistics Department, Iowa State University, Ames, Iowa.

Gulley, J. L.
1974 "Beliefs and Values in American Farming." ERS-558. Washington, D.C.: Economics Research Service, United States Department of Agriculture.

Heady, Earl O., and Luther G. Tweeten
1963 Resource demand and structure of the agricultural industry. Ames, Iowa: Iowa State University Press.

Hoffmann, R. A., and E. O. Heady
1962 "Production, income and resource changes from farm consolidation." Research Bulletin 502. Agricultural and Home Economics Experiment Station. Ames, Iowa: Iowa State University.

Intriligator, Michael D.
1978 Econometric models, techniques, and applications. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Johnston, J.
1972 Econometric methods, 2nd ed. New York: McGraw-Hill Book Company.

Johnson, S. S., and E. O. Heady
1962 "Demand for labor in agriculture." CAEA 13. Center for Agricultural and Economic Adjustment. Iowa State University, Ames, Iowa.

Just, Richard E.
1974 "An investigation of the importance of risk in farmers' decisions." American Journal of Agricultural Economics 56: 14-25.

Koyck, L. M.
1954 Distributed lags and investment analysis. Amsterdam: North-Holland Publishing Company.

Minden, Arlo J.
1965 Domestic demand functions for new farm machinery. Unpublished Ph.D. dissertation, Library, Iowa State University, Ames, Iowa.

Nerlove, Marc
1958 Distributed lags and demand analysis for agricultural and other commodities. Agriculture Handbook No. 141. Washington, D. C.: Agricultural Marketing Service, United States Department of Agriculture.

Pindyck, R. S., and D. L. Rubinfeld
1976 Econometric models and economic forecasts. New York: McGraw-Hill Book Company.

Theil, Henri
1971 Principles of econometrics. New York: John Wiley and Sons, Inc.

Tweeten, Luther G.
1962 "An Economic Analysis of the Resource Structure of United States Agriculture." Unpublished PhD dissertation. Library, Iowa State University, Ames, Iowa.

United States Department of Agriculture
1962 Agricultural statistics, 1962. Washington, D.C.: United States Government Printing Office.

1969a "Farm population and employment." Major statistical series of the U.S. Department of Agriculture: How they are constructed and used. Agriculture Handbook No. 365, Vol. 7. Washington, D.C.: United States Government Printing Office.

1969b "Gross and net farm income." Major statistical series of the U.S. Department of Agriculture: How they are constructed and used. Agriculture Handbook No. 365, Vol. 3. Washington, D.C.: United States Government Printing Office.

1970 "Agricultural prices and parity." Major statistical series of the U.S. Department of Agriculture: How they are constructed and used. Agriculture Handbook No. 365, Vol. 1. Washington, D.C.: United States Government Printing Office.

1971a "Crop and livestock estimates." Major statistical series of the U.S. Department of Agriculture: How they are constructed and used. Agriculture Handbook No. 365, Vol. 8. Washington, D.C.: United States Government Printing Office.

1971b "Land values and farm finance." Major statistical series of the U.S. Department of Agriculture: How they are constructed and used. Agriculture Handbook No. 365, Vol. 6. Washington, D.C.: United States Government Printing Office.

1972 Agricultural statistics, 1972. Washington, D.C.: United States Government Printing Office.

1973 Agricultural statistics, 1973. Washington, D.C.: United States Government Printing Office.

1978 Agricultural statistics, 1978. Washington, D.C.: United States Government Printing Office.

United States Department of Agriculture, Economics Research Service
1960 The Balance Sheet of Agriculture 1960. Agriculture Information Bulletin 232. Washington, D.C.: United States Department of Agriculture.

1965 The Balance Sheet of Agriculture, 1965. Agriculture Information Bulletin 290. Revised Sept. 1965. Washington D.C.: United States Department of Agriculture.

United States Department of Agriculture, Economics, Statistics and Cooperatives Service
1978 Farm Income Statistics. Statistical Bulletin No. 609. Washington, D.C.: United States Department of Agriculture.

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APPENDIX A. VARIABLES AND SOURCES

The variables used in this analysis are defined in this appendix. The sources of these variables are also listed. In the analysis many price ratios are used, these are simply the ratios of the appropriate variables listed below.

The number and size of farms in the U.S. are estimated on January 1 of the current year.

A' = the national average number of acres per farm (Durost and Black, 1978)

N = the number of farms in the U.S. (United States Department of Agriculture, Economics, Statistics, and Cooperative Service, 1978)

Several price indices are used in the analysis. These prices all stand for the index of the national average price of the commodity indicated below and are found in Agricultural Statistics (United States Department of Agriculture, 1978, 1973, 1972, 1962). All indices have the 1967 value equal to 100. Exceptions are noted where needed.

P_B = building and fencing materials

P_c = pesticides (Durost, 1979)

P_{CRP} = aggregate prices received by farmers for crops

P_e = electricity on farms (Durost, 1979)

P_{fd} = feed

P_{FL} = average per acre value of all U.S. farmland

P_{fo} = fuel and oil on farms (Durost, 1979)

P_{fr} = fertilizer and lime

P_H = hourly farm wage rate index

P_{LK} = aggregate price received by farmers for livestock and livestock products

P_M = all farm machinery

P_o = all agricultural operating inputs

P_P = aggregate price paid by farmers for all resources

P_R = aggregate price received by farmers for all commodities

P_s = agricultural seed

Total expenditures for resources are measured in million dollars at the 1967 value; the 1967 value is obtained by dividing the current value of expenditures by the appropriate price index (1967: 1.0). The abbreviations defined below are for U.S. farmers' total expenditures for the resource indicated. The data source is United States Department of Agriculture, Economics, Statistics, and Cooperatives Service (1978) unless noted differently.

Q_B = buildings, excluding operators' dwellings, and land improvements

Q_c = pesticides for crop use (Durost, 1979)

Q_e = electricity for farm use (Durost, 1979)

Q_{fd} = feed for livestock

Q_{fo} = fuel and oil for farm use (Durost, 1979)

Q_{fr} = fertilizer and lime for agricultural use

Q_M = all farm machinery for farm use

Q_o = all agricultural operating inputs

Q_s = seed for farm use

The labor force in the U.S. is measured in thousands of people employed. The data source is Agricultural Statistics (United States Department of Agriculture, 1978 and 1972). The total labor force is analyzed as two separate components, the hired and family forces.

Q_F = the national family farm labor force

Q_H = the national hired farm labor force

The exogenous variables used in this analysis are from several sources. The definition of each variable and the data source are listed below.

E = the ratio of U.S. farmers' total equity to their total outstanding debt for farming purposes (Evans and Simunek, 1978)

P_{IS} = the index of the national average price of metals and metal products adjusted by the consumer price index (Council of Economic Advisors, 1978)

P_N = the index of the national average hourly wage rate of all nonfarm, industrial workers adjusted by the consumer price index (Council of Economic Advisors, 1978)

S_B = the stock of farm buildings excluding operators' dwellings on January 1 of the current year (Evans and Simunek, 1978)

S_M = the stock of farm machinery on farms on January 1 of the current year (Evans and Simunek, 1978; United States Department of Agriculture, Economic Research Service, 1965; and United States Department of Agriculture, Economic Research Service, 1960)

T = the time variable which represents slowly changing variables (T = 47.0 for 1947)

TA = the national crop acreage (United States Department of Agriculture, 1978, 1972)

TSQ = the squared value of the time variable, T

U = the national average unemployment rate, $0 \leq U \leq 1$ (Council of Economic Advisors, 1978)

UY_R = the product of U and Y_R

V = the three-year simple average of variation between expected and actual national net farm income (calculated from United States Department of Agriculture, Economics, Statistics, and Cooperatives Service, 1978)

X = the national value of net agricultural exports (United States Department of Agriculture, 1978, 1972)

Y_{AF} = the three-year simple average of national net farm income (calculated from United States Department of Agriculture, Economics, Statistics and Cooperatives Services, 1978)

Y_D = personal disposable income for the entire population, farm and nonfarm, deflated by the consumer price index (United States Department of Agriculture, Economics, Statistics, and Cooperatives Services, 1978)

Y_R = the index of the ratio of nonfarm to farm national average hourly wage rates (calculated from data in Council of Economic Advisors, 1978)

The consumer price index used to adjust the general measures to 1967 values is obtained in United States Department of Agriculture (1978, 1972). Where possible, price indices applicable to a measure are used to adjust to 1967 values.

APPENDIX B. PROJECTION MODELS

The estimated coefficients of the projection and reduced form models are presented in this appendix. The coefficients for the projection models of expenditures for farm machinery, building and land improvements, fuel and oil, electricity, hired and family farm labor (in thousands of workers), and aggregate operating inputs are in Table B.1. The estimated reduced form models for the seed, fertilizer and lime, and pesticide system are presented in Table B.2. The estimated reduced form models for the feed system are in Table B.3. These models are used to project the use and mix of agricultural resources in the U.S. in 1990. To do this, estimates of the exogenous variables are needed; the projection models of the exogenous variables are in Table B.4.

Table B.1. Projection models of expenditures for farm machinery, building and land improvements, fuel and oil, electricity, hired and family farm labor[a], and aggregate operating inputs.

Variable	s^2	R^2	Intercept	TA_t	E_t
Q_M	342,751	.500	-51,842 (32,000)	15 (18)	154 (363)
Q_B	6,838	.947	13,615 (4,520)	-11 (3)	-31 (51)
Q_{fo}	2,233	.959	-8,502 (2,583)	5.6 (1.5)	-41 (29)
Q_e	100	.996	-725 (547)	-.02 (.31)	4 (6)
Q_H[a]	2,361	.991	460 (2,883)	4.1 (1.7)	-7.4 (32.0)
Q_F[a]	2,921	.999	13,757 (3,207)	10 (2)	-28 (36)
Q_o	41	.989	-88 (77)	-[b]	.9 (2.7)

[a]Estimated in thousands of workers.

[b]This variable is not included in the projection model specification. The model is estimated without this variable.

Y_{AFt-1}	V_{t-1}	Y_{Rt-1}	UY_{Rt-1}	P_{ISt}
.63	-.00008	6,749	-6,150	-30
(.18)	(.00003)	(2,709)	(5,626)	(40)
.02	-.0000003	321	566	.7
(.03)	(.0000048)	(383)	(795)	(5.7)
.03	-.000006	-138	405	5.1
(.01)	(.000003)	(219)	(454)	(3.3)
.001	-.0000003	-56	352	-.57
(.003)	(.0000006)	(46)	(96)	(.69)
-.01	.0000008	352	1,780	-1.3
(.02)	(.0000029)	(253)	(490)	(3.4)
.04	.000008	522	1,710	-14
(.02)	(.000003)	(282)	(545)	(4)
-[b]	-[b]	-43	18	-[b]
		(16)	(57)	

Table B.1. Continued

Variable	P_{Nt}	S_{Bt}	T	TSQ
Q_M	89	-.04	183	-[b]
	(138)	(.10)	(204)	
Q_B	-28	.03	11	-[b]
	(20)	(.01)	(29)	
Q_{fo}	-24	.02	77	-[b]
	(11)	(.01)	(17)	
Q_e	-5.6	.002	24	-[b]
	(2.4)	(.002)	(3)	
Q_H[a]	-41	-.02	-26	.52
	(12)	(.01)	(70)	(.54)
Q_F[a]	-47	-.042	-444	3.2
	(13)	(.009)	(78)	(.6)
Q_o	3.1	-[b]	1.3	-[b]
	(.8)		(1.2)	

Table B.2. Reduced form models for the seed, fertilizer and lime, and pesticide system.

Variable	s^2	R^2	Intercept	Q_{st-1}	Q_{frt-1}
Q_{st}	522	.991	345 (1,399)	.20 (.26)	.01 (.10)
Q_{frt}	8,221	.995	3,103 (5,553)	1.1 (1.0)	-.54 (.39)
Q_{ct}	1,807	.995	-5,203 (2,603)	.01 (.48)	-.08 (.18)
N_{t+1}	491	1.000	3,974 (1,358)	.42 (.25)	-.21 (.09)
$\frac{P_s}{P_{CRPt}}$	.0022	.939	-7.9 (2.9)	.00002 (.00054)	.0002 (.0002)
$\frac{P_{fr}}{P_{CRPt}}$	.0026	.895	-4.9 (3.1)	.0005 (.0006)	.0003 (.0002)
$\frac{P_c}{P_{CRPt}}$	.0028	.936	-8.6 (3.3)	.0001 (.0006)	.0006 (.0002)
$\frac{P_R}{P_{pt}}$	.0022	.964	2.0 (2.9)	-.0012 (.0005)	.0001 (.0002)

$\hat{Q}_{Ct-1}$	N_t	$\frac{P_s}{P_{CRPt-1}}$	$\frac{P_{fr}}{P_{CRPt-1}}$	$\frac{P_C}{P_{CRPt-1}}$	$\frac{P_R}{P_{Pt-1}}$
-.19 (.14)	-.10 (.11)	196 (134)	-29 (163)	145 (102)	244 (174)
.80 (.54)	-.53 (.45)	690 (533)	-435 (647)	373 (405)	1,403 (692)
.37 (.26)	.28 (.21)	153 (250)	-90 (303)	65 (190)	330 (325)
.17 (.13)	.61 (.11)	86 (130)	-396 (158)	-88 (99)	-579 (169)
-.0003 (.0003)	.0006 (.0002)	-.23 (.28)	.26 (.34)	-.05 (.21)	-.22 (.36)
-.0006 (.0003)	.0004 (.0003)	-.28 (.30)	.55 (.36)	-.23 (.23)	-.23 (.39)
-.0007 (.0003)	.0005 (.0003)	-.24 (.31)	.97 (.38)	.10 (.24)	-.03 (.41)
.0003 (.0003)	.0001 (.0002)	-.20 (.27)	.15 (.33)	.09 (.21)	.68 (.36)

Table B.2. Continued

Variable	E_t	Y_{AFt-1}	V_{t-1}	P_{Nt}
Q_{st}	2 (13)	.01 (.01)	-.0000005 (.0000014)	-4 (8)
Q_{frt}	-80 (53)	.02 (.03)	-.000003 (.000005)	-18 (33)
Q_{Ct}	33 (25)	.004 (.012)	-.000001 (.000003)	-3 (2)
N_{t+1}	25 (13)	.03 (.01)	-.000003 (.000001)	-10 (8)
$\frac{P_s}{P_{CRPt}}$	.006 (.028)	.00001 (.00001)	-.00000001 (.00000000)	.002 (.017)
$\frac{P_{fr}}{P_{CRPt}}$	-.02 (.03)	-.000003 (.000015)	.00000000 (.00000000)	-.001 (.002)
$\frac{P_c}{P_{CRPt}}$	.06 (.03)	.00003 (.00002)	-.00000000 (.00000000)	.06 (.02)
$\frac{P_R}{P_{pt}}$	.01 (.03)	-.00002 (.00001)	.00000000 (.00000000)	-.006 (.017)

X_t	Y_{Dt}	T
1.1 (.8)	.002 (.001)	-10 (14)
-2.0 (3.3)	.007 (.003)	-40 (54)
-3 (2)	.003 (.001)	1 (25)
-.45 (.80)	.001 (.001)	-25 (13)
-.004 (.002)	-.000001 (.000001)	.11 (.03)
-.001 (.002)	-.000004 (.000002)	.06 (.03)
-.001 (.002)	-.000005 (.000002)	.04 (.03)
.002 (.002)	.000003 (.000001)	-.03 (.03)

Table B.3. Reduced form models for the feed system.

Variable	s^2	R^2	Intercept	N_t
Q_{fdt}	31,169	.992	23,288 (4,686)	-2.0 (0.4)
N_{t+1}	898	.999	2,832 (796)	.69 (.08)
$\frac{P_{fd}}{P_{LKt}}$	.0051	.673	-.8 (1.9)	.00004 (.00018)
$\frac{P_R}{P_{pt}}$	.0021	.950	3.4 (1.2)	-.00009 (.00011)

$\frac{P_{fd}}{P_{LKt-1}}$	$\frac{P_R}{P_{pt-1}}$	E_t	Y_{AFt-1}	X_t
-3,688 (417)	-2,801 (821)	298 (78)	.08 (.04)	-2.6 (3.4)
-47 (71)	-226 (139)	41 (13)	.017 (.007)	.27 (.58)
.73 (.17)	.97 (.33)	-.05 (.03)	-.00002 (.00002)	.002 (.001)
-.33 (.11)	.38 (.21)	.02 (.02)	-.0000001 (.0000103)	.0029 (.0009)

Table B.3. Continued

Variable	Y_{Dt-1}	T
Q_{fdt}	.011 (.002)	-182 (59)
N_{t+1}	.0013 (.0003)	-42 (10)
$\frac{P_{fd}}{P_{LKt}}$	-.000001 (.000001)	.01 (.02)
$\frac{P_R}{P_{pt}}$	.000001 (.000001)	-.05 (.02)

Table B.4. Projection models for exogenous variables.

Variable	s^2	R^2	Intercept	T
TA_t	247	.886	1,434 (19)	-4.6 (.3)
E_t	.80	.875	22.7 (1.1)	-.25 (.02)
Y_{AFt-1}	9,534,632	.410	32,830 (3,677)	-270 (59)
V_{t-1}	1.19×10^{14}	.112	-17,769,982 (12,991,605)	405,782 (208,904)
P_{ISt}	41.6	.523	56 (7)	.71 (.12)
P_{Nt}	7.2	.971	-11 (3)	1.6 (.1)
S_{Bt}	3,786,533	.321	24,203 (2,317)	140 (37)
Y_{Rt-1}	.02	.093	1.67 (.18)	.005 (.003)
UY_{Rt-1}	.001	.262	-.004 (.031)	.002 (.001)
X_t	212	.879	-163 (17)	4.1 (.3)
Y_{Dt}	5.84×10^{8}	.975	-526,596 (28,767)	15,917 (463)